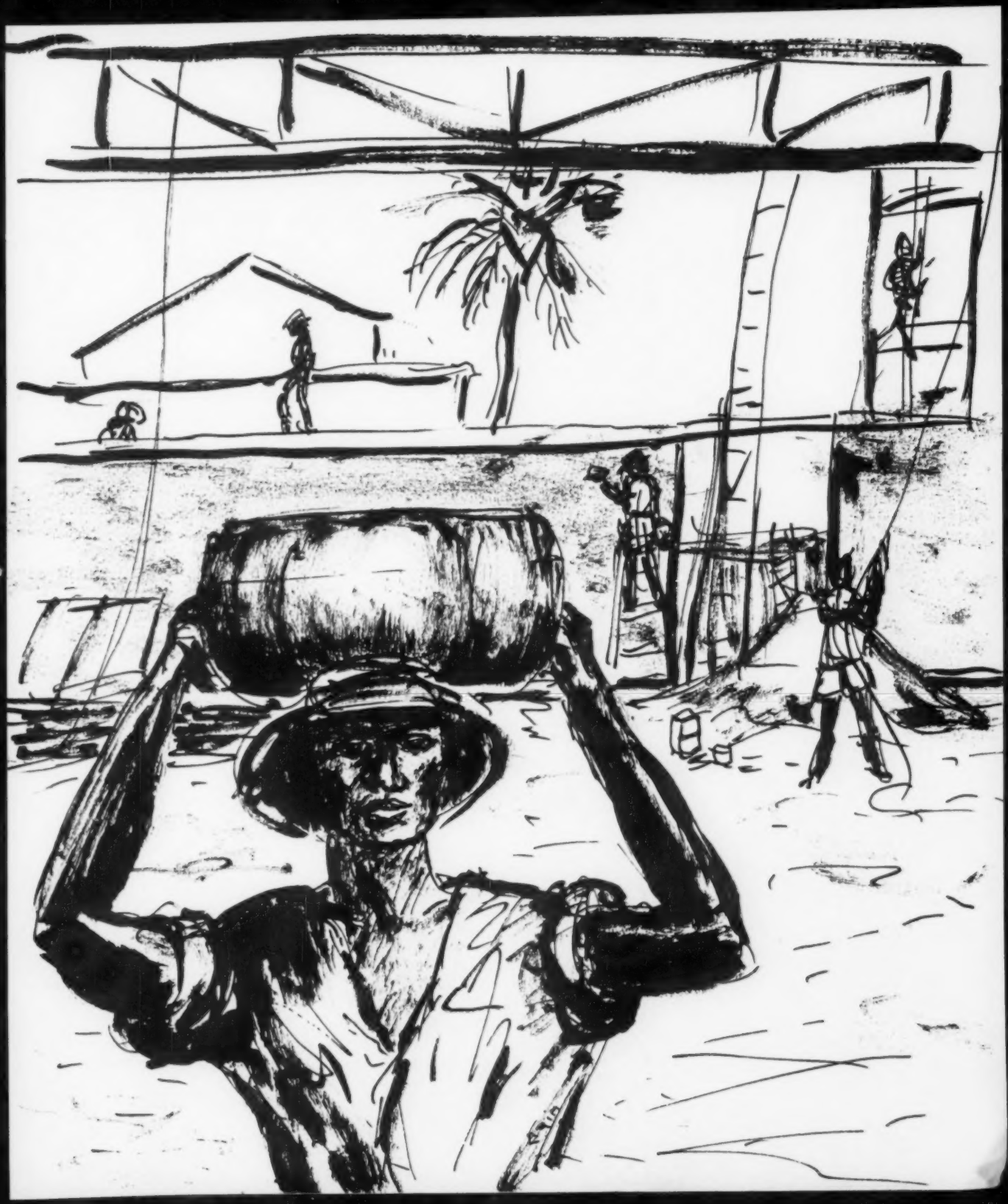
JOURNAL OF

METALS

MAY 1960



One of a series

Catching Up with a Slippery Equation

What goes on when two moving surfaces are separated by a film of oil?

Simple question? Maybe, but engineers and mathematicians have been trying to answer this classic question of lubrication ever since Osborne Reynolds neatly stated the problem in equation form back in 1886.

Unfortunately, analytical methods for solving Professor Reynolds' partial differential equation worked only for unrealistic oil bearings, bearings with widths approaching zero or infinity. And approximate methods were crude, requiring a complete recalculation for each slight change in the bearing.

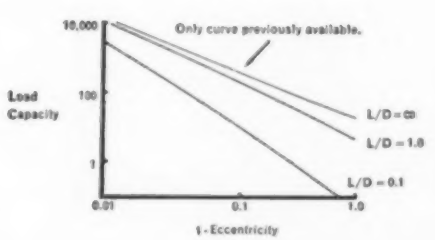
Recently, mathematicians at the General Motors Research Laboratories came up with the most versatile and efficient method of solution yet made. Their analytical method for solving the two-dimensional Reynolds' equation applies to all finite journal bearings – as well as other hydrodynamic bearings – with *no* assumptions or approximations about boundary locations. The new method uses a long-neglected energy theorem recorded by Sir Horace Lamb instead of the force relationship tried by Reynolds and others.

Besides being a valuable contribution to the theory of lubrication, this work has its practical side: namely, accurate, serviceable design curves for engineers. At GM Research, we believe delving into both the theoretical and applied sides of a problem is important to progress. It is a way of research that helps General Motors fulfill its pledge of "more and better things for more people."

General Motors Research Laboratories

Warren, Michigan

Hydrodynamic analyses have led to specific answers about bearing operation. Shown here are the oil pressure distribution (main illustration) and load-carrying capacity for a non-rotating journal with a reciprocating load.



JOURNAL OF

METALS

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May , 1960

COVER: Africa, the continent of vast and untapped resources, is making the first-steps toward industrialization. . . . The cover by David Cain was inspired by the article on African aluminum (p. 385).

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personnel

• These items are listings of the Engineering Societies Personnel Service, Inc. This Service, which cooperates with the societies of Civil, Electrical, Chemical Mechanical, Mining, Metallurgical, and Petroleum Engineers, is available to all engineers, members and non-members, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 5% of the first year's salary if a non-member, or 4% if a member. Also, that you will agree to sign our placement fee arrangement which will be mailed to you immediately, by our office, after receiving your application. In sending applications be sure to list the key and job number.

• When making application for a position include eight cents in stamps for forwarding application to the employer and for returning when possible.

—MEN AVAILABLE—

All those listed under "Men Available" have membership in the AIME.

Welding Metallurgist; B. Met. E., with 40 graduate credits in metallurgy. One year experience with mechanical properties of steel at subzero temperatures; three years welding research and development. Seek R&D position with primary producer or heavy equipment fabricator. Age 24, draft deferred. Prefer New York metropolitan area. M-228.

Metallurgist; B.S. and M.S. Met. Eng., Masters thesis in strain-aging of heavy-section pressure vessel steels. Experince in protective coatings for nickel, cobalt and refractory alloys . . . evaluation of mechanisms of coating protection and failures . . . all phases heat treatment of turbine materials and steel. Prefer northern N. J. M-229.

Manager of Metallurgical Research; B.S. and M.S. Met. Eng., age 38. Fourteen years research experience (nuclear and both ferrous and nonferrous); four years supervisory experience; five years as group leader doing nuclear research. Leadership ability as well as technical competence. Location secondary to opportunity. M-230.

Management Level Engineer; B.S. and M.S. in Met. Eng., age 36. Qualified administrator; experienced as director of engineering and manufacturing in specialized foundry, powdered metallurgy, fabrication, heat treatment. Also in magnetic alloys and refractory metals. Desire management position with progressive company. Three years South Africa. Locate anywhere. M-231.

Foreman or Superintendent; MetE, age 28. Seven years experience in charge of crews developing undercut blocks in block caving . . . safety inspection . . . cut and fill stopes . . . flotation mil . . . and underground surveying on copper and molybdenum mining. $8500. Prefer Western US or foreign. Se-1648.

R&D; M.E. in Phys. Met., age 39. Seven years research on metals and teaching assistant for university. One year in application of heat treatment of metals. $7000. Prefer San Francisco East Bay. Se-1151.

Manager or Superintendent; age 53. Thirteen years manager of mines, supervising all production, purchasing, operations, negotiating labor contracts, exploration and development. Twenty-five years mill superintendent, supervising maintenance, ore dressing, operations, (lead, zinc, silver, copper, gold, mercury operations). $9600. Prefer West. Se-903.

Manager; MinE, age 62. Thirty-six years experience (domestic and foreign) as general manager and superintendent on mills, mines, construction, development, operations, and facilities. Mining of gold, silver, base metals. $12,000. Prefer Southwest or any. Se-864.

Supervisor; graduate MinE, Met, age 55. Thirty years experience in examination, exploration, development, and operation in nonferrous metal mines, mills, and allied fields. Licensed prof engr. $7800. Prefer West. Se-1580.

Mill Superintendent; age 63. Thirty years experience in ore dressing research and operation of nonferrous ore or beneficiation plants. Proven ability to cut costs and increase recoveries. Locate anywhere in US. Salary, open. Se-461.

Metallurgist; graduate, age 24. One year as process engineer, developing and improving new and existing metallurgical practices on electric furnace manufacture of ferro and special intermediate alloys; small-scale pilot work for refractory. One year as production engineering trainee doing development for ferro alloys and calcium carbide manufacturing. $7000. Prefer San Francisco Bay area or West. Se-1214.

Metallurgist; graduate, age 40. Eleven years supervising personnel and metallurgy in lead smelters . . . research on casting techniques at cadmium refinery . . . foreman at copper refinery . . . foreman of aluminum rolling mill. $8400. Prefer Calif. or Northwest. Se-927.

Mill Superintendent; four years college (ore dressing), age 51. Many years experience as mill superintendent and consultant on silver, lead, copper, cobalt, tungsten, iron. $9600. Perfer West or any. Se-263.

Process or Physical Metallurgist; MetE, age 26. Two years as metallurgical engineer in quality control and heat treating in nonferrous sand castings foundry; one year operation of pilot plant for extraction in copper smelter. Two years instructor in fundamentals of electronics, Air Force. $7200. Prefer West, North, or Central US. Se-159.

Production or Management Engineer; MinE, age 41. Eighteen years experience in mining and mineral dressing in non-metallics—underground, open pit, all phases mineral dressing. Also experienced in exploration, research and development, and design and construction. Staff engineering background in costs, estimating and budgeting, and reports. Desire production or engineering management position. $12,000. Prefer West Coast but other locations acceptable. Se-1740.

—POSITIONS OPEN—

Address replies for positions to the nearest local office of the Engineering Societies Personnel Service, Inc., *not* to the JOURNAL OF METALS. Offices are located at 29 E. Madison St., Chicago 1, Ill. . . . 57 Post St., San Francisco, Calif. . . . and 8 W. 40th St., New York 18, N. Y.

Metallurgical or Mechanical Engineers for line supervisory positions. Must have foundry background and be heavy on steel. a) Quality Control Manager. b) Assistant General Foreman in charge of cleaning room. c) Assistant General Foreman to run grey iron foundry. Salaries, $7800-$10,000. Location: Pa. W8860.

Associate Editor for trade publication. Experience in metal working. Some experience in writing. Salary, about $7200. Location: New York City. W8846.

Engineers. a) Metallurgist for R&D. To develop new uses in the rare earth field. b) Application engineer, chemist, metallurgist, or physicist having some contact with materials used in electronic vacuum tube parts. Salaries, open. Location: northern N. J. W8845.

Metallurgist. Graduate with approximately three years industrial experience. To assist chief metallurgist in evaluating incoming materials, assist production, and develop new equipment in connection with magnetic materials, nickel iron, and silicon iron alloys for tape and bobbin cores. Salary, about $8500. Location, southern N. J. W8827.

Sales Trainee for metals sales division. Recent graduate in metallurgical, chemical, or mechanical engineering with desire to enter the field of industrial sales. Minor travel during training period. Headquarters: New York City. W8817 (b).

Metallurgical Technologist with three to five years experience in ferrous and nonferrous metallographic analysis. To be responsible for metallurgical investigations of field failures, shop problems, and research investigations. Knowledge of heat treating and welding considered helpful. Salary, $6500. Location: Conn. W8789.

Teaching Personnel for metallurgy department. M.S. degree with a metallurgy major and some industrial experience desirable. Must have enough preparation in basic metallurgy to teach two physical metallurgy courses. Two semesters of physical metallurgy and elective courses in advanced physical metallurgy, foundry engineering, quality control of foundry materials, foundry practices and one in metallurgical inspection. Courses provide basic training for students working for degree in mechanical engineering or industrial engineering. Salary, $6600 to $9000. Location: Mich. W8762.

Sales Representatives to handle rare earths. Must understand problems foundries encounter on difficult castings. Knowledge of metallurgy or experience in selling to foundries helpful. Several territories with active accounts open. Headquarters: New York City. W8734.

Metallurgist or Chemist; Chem, Met-Chem or Met, for work in analytical lab and extractive metal research. Degree and several years experience and ability for research is desired. Salary, open. Location: Mont. Sj-5139.

Sales Engineer; graduate with minimum of five years foundry or other industrial experience relating to metallurgy. Will provide technical sales assistance on ferrous castings and in-plant responsibility for metallurgy or production and applied research and development. Ferrous foundry. Salary, $7200 to $9600. Location: San Francisco East Bay. Sj-5090.

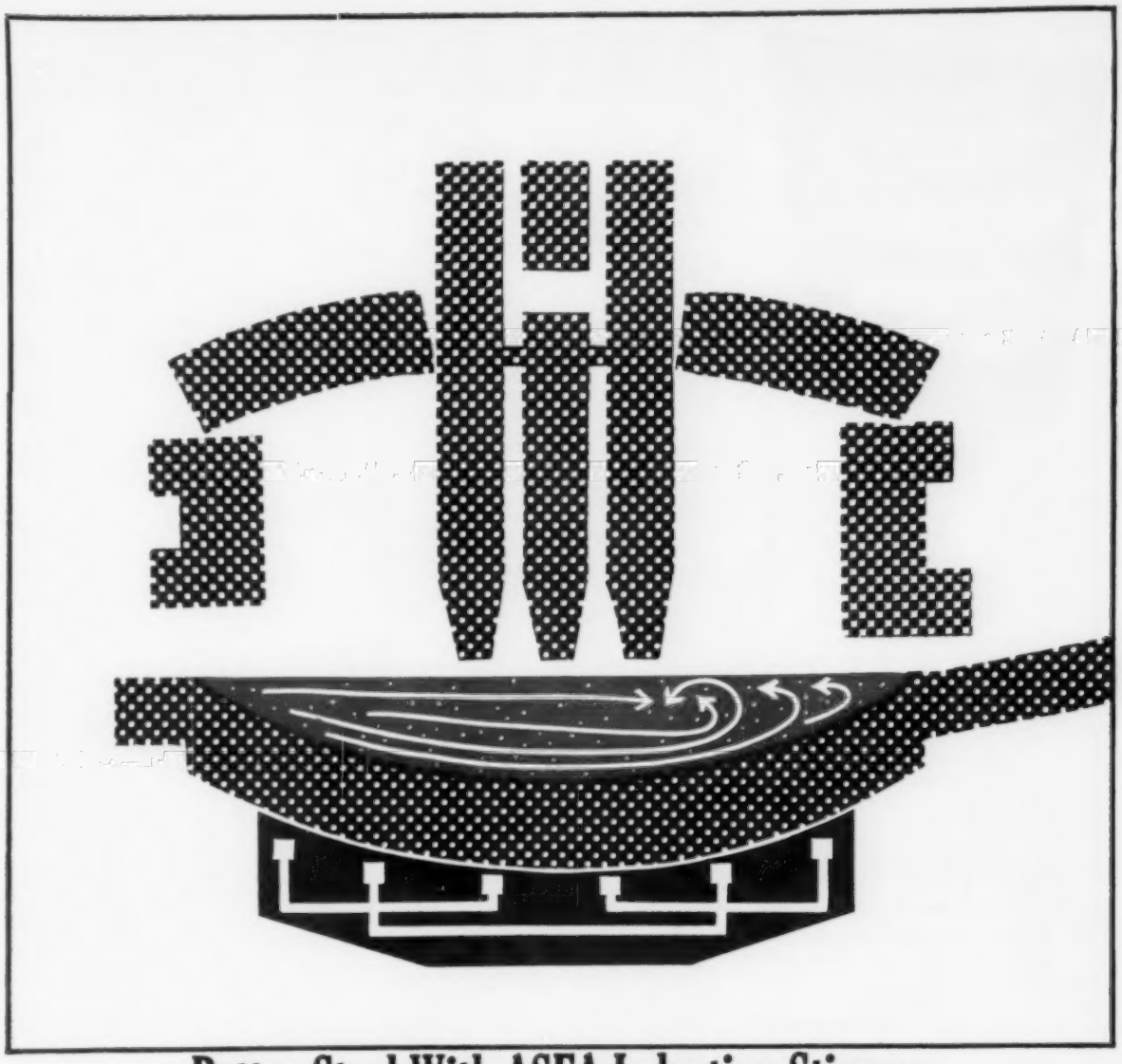
Sales Engineer with knowledge of application of aggregate and metallic processing machinery for aggregate products, metallurgical field, and processing. $6000 guarantee to start, plus expenses, car, and commission. Manufacturer's agent. Location: N. Calif. and W. Nev. Sj-5092.

NEW BULLETIN

A new bi-weekly bulletin of "Engineers Available" is now being published by the Engineering Societies Personnel Service, Inc. Distributed free of charge, the bulletin contains synopses of the experience of engineers who have registered with the Service and are seeking a new position.

Any employer interested in receiving the bulletin should so advise E.S.P.S. at 8 W. 40th St., New York 18, N.Y., and your name will be placed on the mailing list. Any engineer who is registered with the Service or wishes to register is entitled to a 35-word notice in the bulletin. Write to the New York office for forms. Your qualifications will be brought to the attention of employers on our mailing list without revealing your identity.

It is planned to extend the publication to the midwestern and western offices in the near future.



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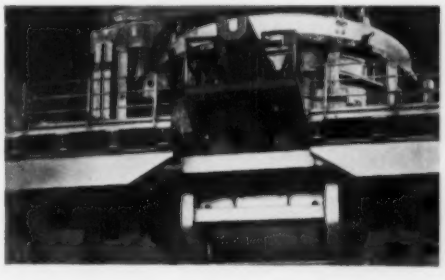

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Analysis of Deformation, Vol. 4: Waves and Vibrations, by Keith Swainger, *The Macmillan Co.*, 370 pp., $15, 1959—In this fourth volume on wave mechanics and vibration, the formulation of the theory of deformation is examined for the propagation of stress through, and on the surface of, substances possessing various physical properties: elasticity, plasticity, fluidity, and combinations of these effects. The effect of rate of load application and reduction on the speed of wave propagation is studied. The classical analyses are given and examined critically and, in some cases, questioned. •

Elements of Ion Exchange, by Robert Kunin, *Reinhold Publishing Corp.*, 164 pp., $5.75, 1960— Specifically written for those with little or no theoretical background in physics, this book provides a basic view of ion-exchange technology. Most of the book is devoted to the nature of materials involved, their structure, the techniques of testing and evaluation, and both general and specific principles of their application. Ion exchange engineering and design practice is also presented in a brief chapter. •

Advanced Engineering Mathematics, 2nd Edition, by C. R. Wylie, Jr., *McGraw-Hill Book Co.* Inc., 696 pp., $9, 1960—This edition is designed as an introduction to those branches of mathematics relevant to the engineer and physicist. It contains a new chapter on determinants and matrices, and one on finite differences which includes the theory of orthogonal polynomicals and the techniques of numerical analysis. Ordinary, linear, and simultaneous linear differential equations are covered thoroughly, and the section on partial differential equations includes solution by Laplace transform. Detailed treatment also is accorded the Fourier series, Bessel functions, Legendre polynomials, vector analysis, conformal mapping, and the theory of residues. •

Symposium on Electroless Nickel Plating, *ASTM Special Technical Publication No. 265*, 67 pp., $2.50, 1959—The book is comprised of six American papers on practical and theoretical aspects of the catalytic deposition of nickel-phosphorous alloys by chemical reduction in aqueous solution. Covered are the history of the electroless plating process . . . the chemical reactions involved and the characteristics of the resulting deposits . . . process procedures . . . the advantages and limitations and applications of the process . . . and methods of testing the solutions used. Also included are an examination of patents in the field and a bibliography of 136 references. •

Theory of Mechanical Vibration, by Kin N. Tong, *John Wiley & Sons Inc.*, 348 pp., $9.75, 1960—This treatment of the theory of linear mechanical vibrations uses analytic principles to demonstrate the unity and coherence of the theory and its connection with other engineering sciences. Four sections cover sys-

(Continued on page 360)

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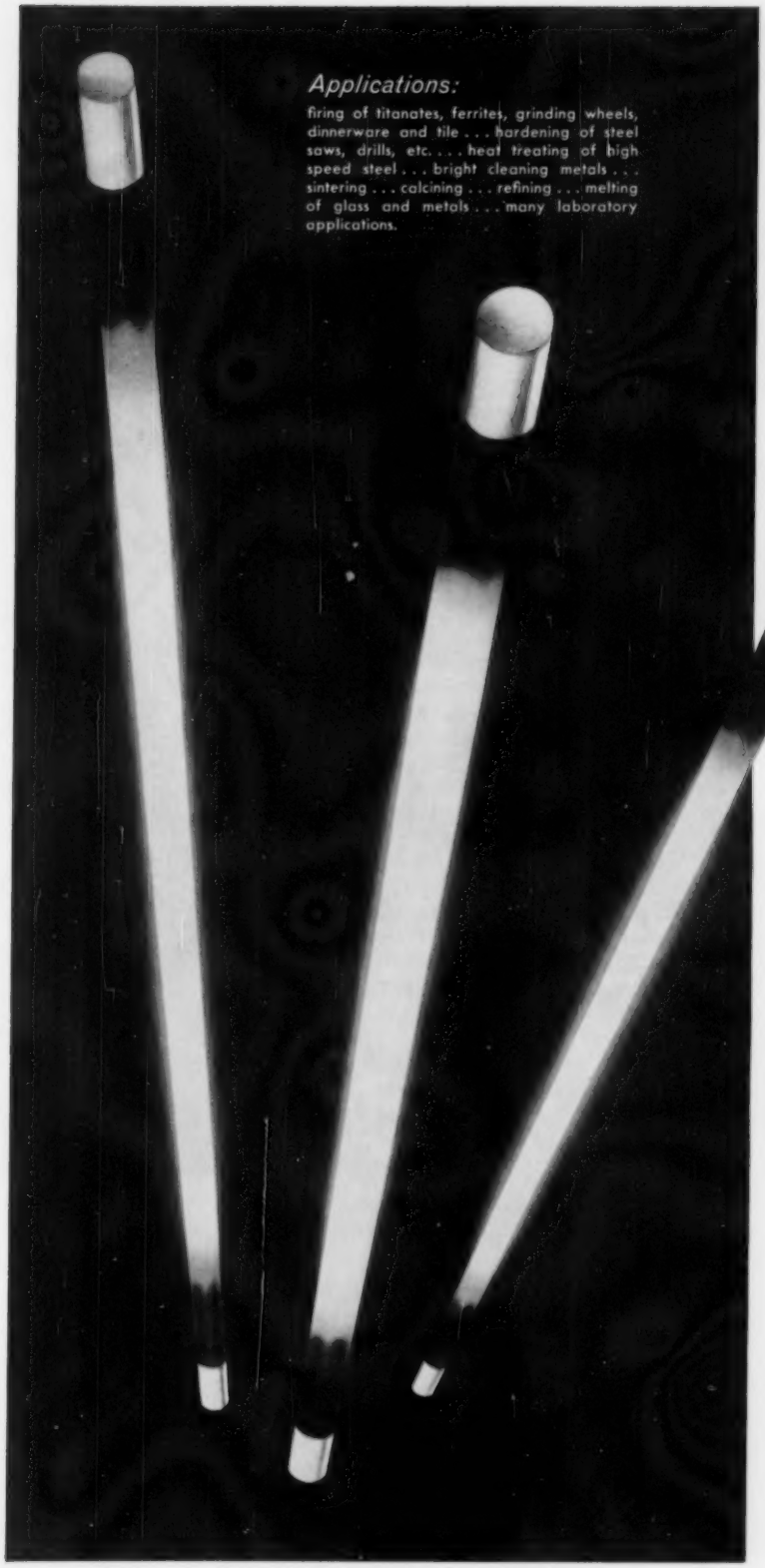
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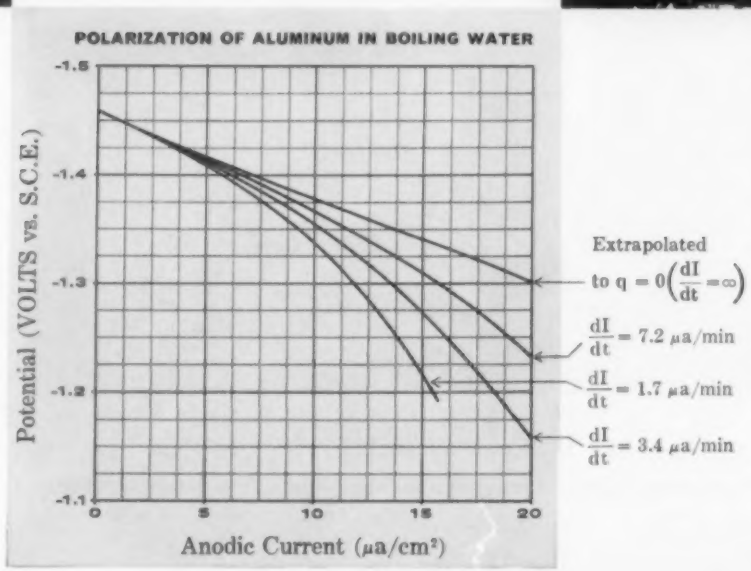

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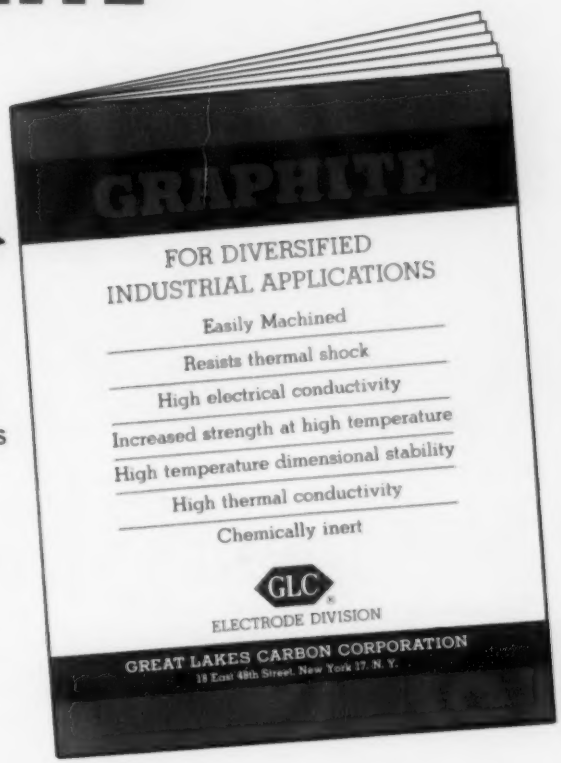

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(Continued from page 356)

tems with a single degree of freedom . . . systems with a multidegree freedom system and the concept of vibration modes . . . an extension of these results through matrix algebra and generalized coordinates . . . and the vibration of continuous media. •

Analytical Chemistry of Titanium Metals and Compounds, by Maurice Codell, *Interscience Publishers Inc.*, 378 pp., $12, 1959—Providing analytical chemists with information necessary for analysis of titanium-containing material is the aim of this work. A general section on the chemistry, sampling and separation procedures, and emission spectograph and vacuum line methods, as applied to titanium, is followed by detailed sections on the determination of metallic and non-metallic elements in titanium and its alloys. The final section contains analyses of titanium-base materials, such as titanium tetrachloride, concentrates, and ores. •

Berichte der Arbeitsgemeinschaft Ferromagnetismus 1958, by *Riederer Verlag*, 136 pp., approx $12, 1959—One of a series of yearly reports from a German group promoting activity in magnetics through research and contact with foreign authorities in the field. This volume includes 24 papers, covering such topics as the Hall effect in ferromagnetic substances . . . investigations on the anomalies of the eddy-current . . . properties of the melting ferrite . . . spontaneous rectangular hysteresis loops in ferrites . . . the magnetic behavior of single crystals in Fe_3Al . . . and others. •

Handbook of Material Trade Names, by O. T. Zimmerman and Irvin Lavine, *Industrial Research Service Inc.*, 440 pp., $16, 1960—Supplements the 1953 edition and its first two supplements by giving completely new information in five sections: an alphabetical list of trade names, with description of the product . . . products classified by major uses or composition . . . list of manufacturers and distributors, giving addresses and names of products . . . company names and address changes for those companies listed in the 1953 edition and its two previous supplements . . . and products previously listed which have been withdrawn from the market. •

Cathodic Protection, by John H. Morgan, *The Macmillan Co.*, 325 pp., $12, 1960—The technique of the electric method of corrosion prevention rather than the electrochemistry of the interface is the subject of this textbook. The book's first part deals with the methods and factors involved in electric corrosion prevention, while succeeding chapters consider the procedures for achieving protection in a variety of structures. •

Jahrbuch der Oberflachentechnik, 1960, edited by W. Wiederholt, *Metall-Verlag GmbH*, 1076 pp., approx $5.60, 1959—This annual volume presents the latest available technical and patent literature of Germany and other countries concerning the mechanical, chemical, and electrochemical treatment of metal surfaces. In addition to survey articles by specialists on various phases of metal-surface treatment, the book contains new data tables, extensive alphabetical or classified listings of trade names, standards, manufacturers, and other information. •

Solid State Physics, Vol. 9, edited by Frederick Seitz and David Turnbull, *Academic Press Inc.*, 548 pp., $14.50, 1959—This ninth volume continues an article on spectra of ions in crystals begun in Vol. 8. Other papers discuss polar semiconductors, static electrification of solids, heterogeneities in solid solutions, the oscillatory behavior of magnetic susceptibility and electronic conductivity, and the interdependence of solid state physics and angular distribution of nuclear radiations. •

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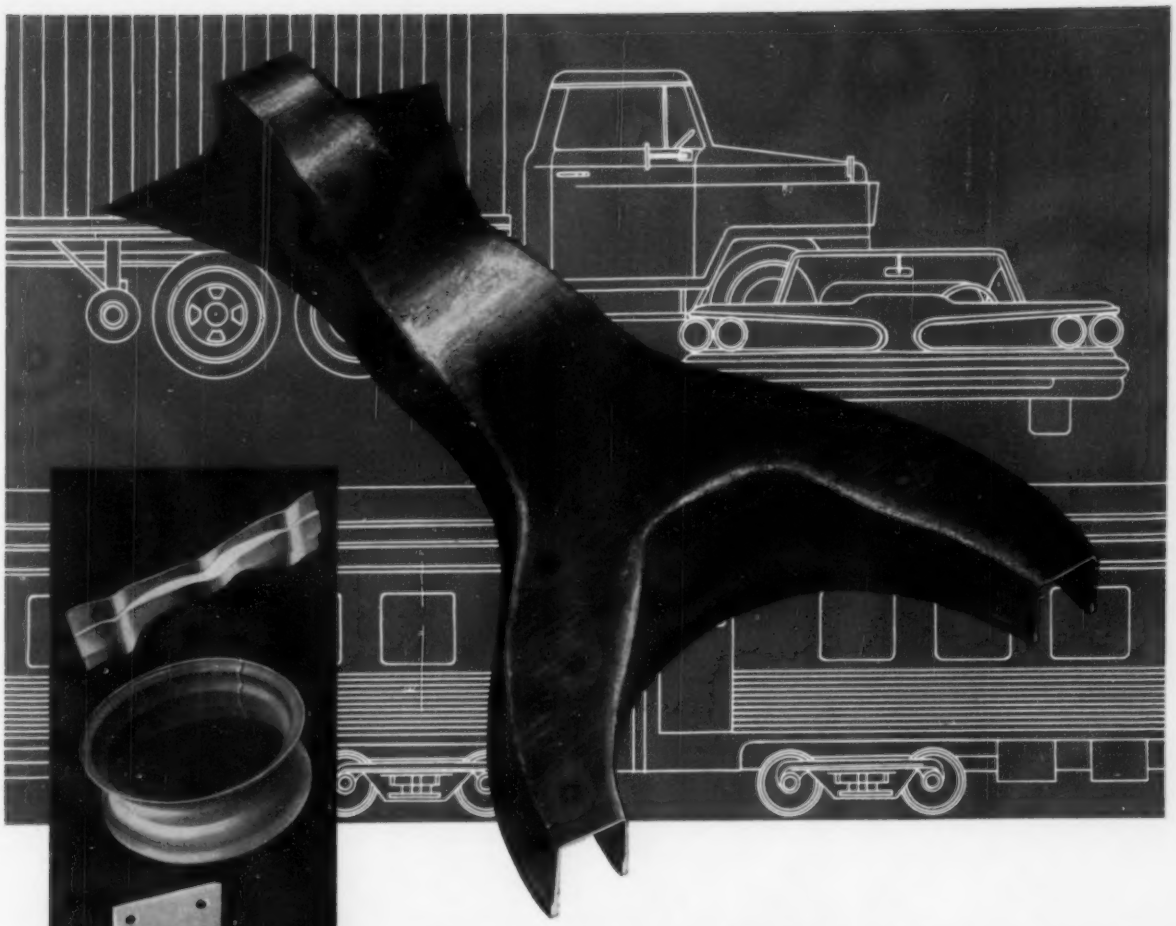


Columbium flat-rolled steels

Do you need a steel, to use in the "as rolled" condition? Or a steel which has high strength, good weldability, good formability?

More and more manufacturers are turning to columbium flat-rolled steel products, for columbium sheet, strip or plate gives an answer to all of these requirements.

Here are just a few examples of columbium steel's wide versatility. Line pipe for gas and oil offers ease of manufacture with excellent physical strength. Trucks, automobiles, farm implements, trailers and railroad cars take advantage of strength and ease of formability. Pressure vessels utilize the deep-drawing qualities of the steel. These applications and many others tell the story of columbium steel's versatility—and all with fewer rejects.

In the face of mounting manufacturing costs, columbium steels offer hope of effecting economies in producing your products. Ask any steel company for they can make it. Or ask us—we have a wide experience in its uses and knowledge of its manufacture.

MOLYBDENUM

2 Gateway Center CORPORATION OF AMERICA **Pittsburgh 22, Pa.**

Offices: Pittsburgh, Chicago, Los Angeles, New York, San Francisco
Sales Representatives: Brumley-Donaldson Co., Los Angeles, San Francisco
Subsidiary: Cleveland-Tungsten, Inc., Cleveland
Plants: Washington, Pa., York, Pa.

MCA

WHAT WILL THE NEW BUILDING COST?

Expenditures:

To the Turner Construction Co. for erection	$8,042,000
Cost of the site, 1st Ave. 47th to 48th Sts. (United Nations Plaza)	2,800,000
Architect's fee	490,000
Necessary non-society equipment to put the building into operation	209,000
Interest on necessary short-term borrowing to meet costs until pledges mature	120,000
Cost of industry and member fund-raising activities, recording and collecting pledges	457,000
Legal fees	145,000
Contingencies	300,000
Total	$12,563,000

Income:

Industrial companies' gifts	$5,400,000
Member gifts from societies to be in the building	3,800,000
Sale of the present building	1,700,000
From depreciation fund, United Engineering Trustees (original four Founder Societies)	1,600,000
From AIChE, as an additional participant in the ownership by the Founder Societies	60,000
Total	$12,560,000

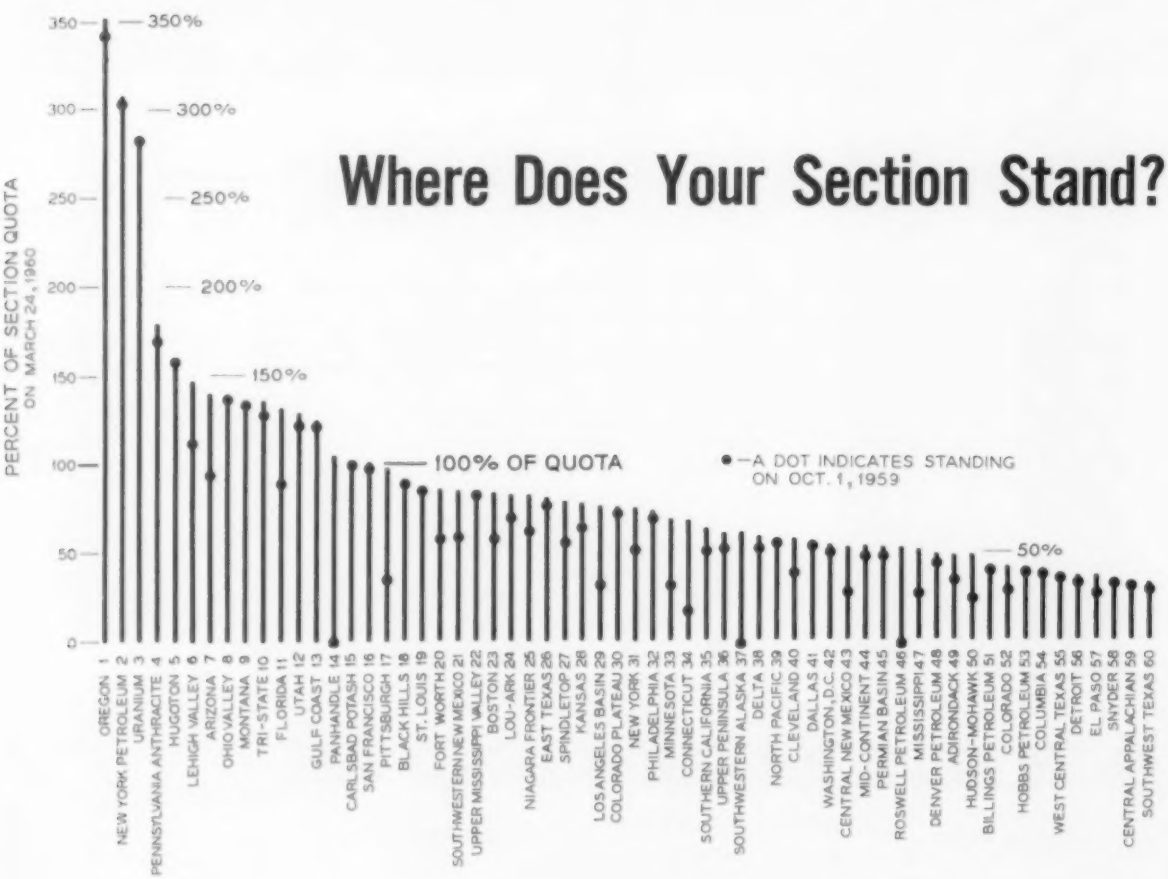
Are Our Faces Red!

Do we want other Engineers to think we (AIME) are Second Class? Twenty-two pct of us have already said NO. Most of the other 78 pct have not been asked personally to contribute. OK—HERE IT IS—Our building is going up but we need a little more money to pay for it. Metallurgical and mining members that have pledged have averaged $76, although the median gift is somewhat less.

Get in touch with your Local Section officers if they have not already

UNITED ENGINEERING CENTER BUILDING FUND CAMPAIGN

Where Does Your Section Stand?



approached you. If you live abroad and have no Local Section send your pledge or contribution direct to the AIME Secretary's office, 29 W. 39th St., New York 18.

Where Does Your Section Stand?

Quotas were set for each Local Section—based 1) on the fact that AIME's share in the Member-Gifts Campaign is $500,000, and 2) on the relative membership of the Local Section. The New York Section is asked to meet $150,000 of this, or $96 per member. The Petroleum Society has agreed to raise an equal amount. This leaves $200,000 to come from mining and metals members in Local Sections outside of New York, or an average of approximately $13 per member.

On the first of April 1960, 15 Local Sections had met or surpassed their goals, as the chart shows. Of these 15, Lehigh Valley, Arizona, Florida, and Panhandle have done much of their work in the last six months. Others that got off to a slow start but have made rapid progress are Pittsburgh, Los Angeles Basin, Connecticut, Southwestern Alaska, Central New Mexico, and Roswell.

It is not too late for the laggard Sections to start NOW. Pledges can still be made for the next three years—1960, 1961, and 1962.

What Will the New Building Cost?

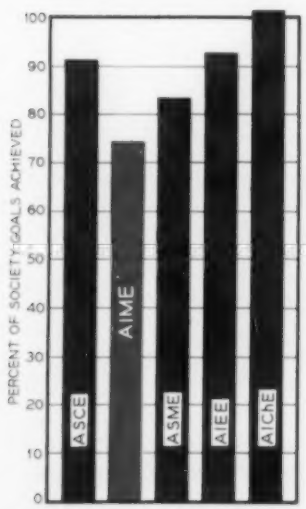
At the meeting of the national Member-Gifts committee for the United Engineering Center on Feb. 23, 1960, William Thompson, chairman of the Real Estate Committee of United Engineering Trustees, presented a statement of the expected income and expenditures for the construction of the new building—see the table, left.

AIME vs the Other Societies

AIME lags behind the other societies in achieving its quota, but there is no reason to think that our members are less inclined to pledge funds for their new headquarters than are the members of other societies. The amount pledged per member has been greater for AIME than in any other society but the number of members who have pledged is relatively less.

Although three-year pledges were provided for in the Member-Gifts campaign, many members paid in full immediately, so 71 pct of all pledges had been paid by Feb. 23, 1960. Cancellation of pledges because of death or other good cause has been nominal.

How is AIME Doing?



United Engineering Center Building Fund Member-Gifts Campaign status as of Jan. 1, 1960

Steel piling rods hover over site just before being dropped to the excavation they will help reinforce. View is southeast toward the corner of UN plaza and 47th St. The UN and Carnegie Building are in the background, center and right.

IMPORTANT McGRAW-HILL BOOKS

METAL FATIGUE

By George Sines, University of California, Los Angeles; and J. L. Waisman, Douglas Aircraft Company. *McGraw-Hill UCLA Engineering Extension Series.* 415 pages, $12.50.

The most rational exposition of fatigue of metals to be found in one book. The editors have sought the leading authority for each subject and put the key information into print. Critically selected bibliographies are provided, and the introduction includes a guide to fatigue literature, for those not thoroughly familiar with the field. The book presents a coordinated advanced treatment, by men who are experts, writing on their own specialties. Much of the subject matter is new.

ENGINEERING MANUFACTURING METHODS, Second Edition

By Gilbert S. Schaller, University of Washington. 682 pages, $9.50.

A straightforward revision of a book that has been very successfully used in Manufacturing Processes courses. Expanded and with new illustrations, the book presents a survey of the entire field of manufacturing in engineering and the manufacture of engineering products. To attain this goal, *every phase* of engineering manufacture is covered. In addition, the introductory chapter deals with the broader phases of management administration as applied to manufacturing.

CONSTITUTION OF BINARY ALLOYS

By Max Hansen, Metallgesellschaft A. G., Frankfurt-Main, Germany; in cooperation with Kurt Anderko, Metallgesellschaft A. G., Frankfurt-Main, Germany. *McGraw-Hill Metallurgy and Metallurgical Engineering Series.* Second Edition. 1305 pages, $35.00.

This revision and translation of the German work provides a source of reliable data concerning the constitution of binary alloy systems (phase diagrams) and the crystal structure of metallic phases. Widely scattered information in the world's metallurgical literature is analyzed and critically evaluated.

PHYSICAL METALLURGY

By C. Ernest Birchenall, Princeton University. 323 pages, $8.50.

The science of metals has taken enormous strides in the past few decades. In this book, the author takes cognizance of the new concepts, theories and experiments in order to produce an elementary text that "reflects in some measure the progress of recent years, the ferment and vitality of the field at present." To provide a sound underlying framework, the book has a strong scientific approach, at the expense of the engineering aspects. This exposition of fundamentals help to emphasize the unity underlying all aspects of the subject. In this respect the book departs significantly from all the other physical metallurgy texts and represents the long-awaited and much-needed approach to the subject.

Send for Copies on Approval

McGRAW-HILL BOOK COMPANY Inc.

330 West 42nd St. New York 36, N. Y.

Expanding the Frontiers of Space Technology

Lockheed Missiles and Space Division is conducting fundamental work in thermal-protection systems for missile and space vehicles and other extended research and development studies in materials and processes. Facilities are located in the Stanford Industrial Park at Palo Alto on the beautiful San Francisco Peninsula – one of the choicest living areas in the nation.

Inquiries are invited from experienced metallurgists for the following:

PHYSICAL METALLURGY

Advanced degree required with experience in modern experimental techniques and research. For responsible position in basic and applied research in metallurgical behavior and mechanisms concerning high temperature and advanced missile materials with interest in metal physics; deformation and fracture; phase equilibria; transformations; or diffusion.

METALLOGRAPHIC RESEARCH

B.S. or M.S. with minimum 3 years' experience in metallography as related to X-ray diffraction, phase equilibrium relationships, and properties.

POWDER METALLURGY – CERAMICS

Advanced degree required with strong background in the basic sciences. To conduct basic and applied studies in refractory metals; dispersed phase systems; fiber metallurgy; ceramics and thermal protective materials systems.

DIFFRACTION RESEARCH

Advanced degree required with background suitable for X-ray and electron diffraction research and studies in single crystals; point defects; parameter measurements; pole figure determinations; phase equilibria and high temperature transformations.

Positions are also available for research laboratory technicians.

Engineers and Scientists – Such programs reach far into the future and deal with unknown and stimulating environments. It is a rewarding future with a company that has an outstanding record of progress and achievement. If you are experienced in any of the above areas, or in related work, we invite your inquiry. Please write: Research and Development Staff, Dept. E-55, 962 W. El Camino Real, Sunnyvale, California. U.S. citizenship or existing Department of Defense industrial security clearance required.

Lockheed / **MISSILES AND SPACE DIVISION**

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CAPE CANAVERAL, FLORIDA • ALAMOGORDO, NEW MEXICO • HAWAII

education

BOOKS

► **Directory of Steel Foundries in the US, Canada, and Mexico, 1959-1960,** published by the Steel Founders' Society of America, $15,—This semi-annual directory lists 449 steel foundries . . . their key personnel . . . types of castings produced . . . weight range . . . alloys . . . special processes . . . melting equipment . . . heat-treating facilities . . . nondestructive testing equipment . . . products . . . number of employees . . . and rated monthly capacity.

Address the *Steel Founders' Society of America, 606 Terminal Tower, Cleveland 13.*

► **Engineering Societies Directory, 1959,** published by the Engineers Joint Council, $3.50—This directory is called "the only comprehensive US listing of engineering and scientific societies, their functional staff personnel and publications." Societies and organizations are listed in the directory, as well as national and international organizations and all state registration boards for professional licensing. A nearly complete listing of Canadian engineering organizations is also included.

For copies, write: *Engineers Joint Council, 29 W. 39th St., New York 18.*

► Fusion Welding Aluminum is the title of the latest Reynolds Metals Co. technical handbook. The 6x9 in. paper-bound book covers gas welding . . . metal arc welding . . . TIG welding . . . straight polarity TIG . . . MIG welding . . . TIG welded joint designs . . . and MIG welded joint designs in its 32 pp. This book, as well as other handbooks on joining—Adhesive Bonding of Aluminum . . . Riveting Aluminum . . . Mechanical Joining of Aluminum . . . Soldering Aluminum . . . Brazing Aluminum . . . and Screw Fastening of Aluminum— is available on letterhead request to the Reynolds Metals Co., Dept. PRD-31, Richmond 18, Va.

► A 12-pp brochure describing the application, physical properties, and production processes of molybdenum has been made available by the Chemical and Metallurgical div., Sylvania Electric Products Inc. The brochure lists the forms of molybdenum available commercially and explores new avenues of application opened through advances in the refractory metals field. For copies, write: Sylvania Electric Products Inc., Chemical and Metallurgical div., Towanda, Pa.

► Sylvania also announces publication of a bibliography on tungsten, which indexes all information on the metal which appeared in US and foreign publications between 1953-1958. The 44-pp book contains 409 references, each of which gives the author, a brief description of the article, and where it appeared. A subject index—a listing of tungsten's physical properties—and 19 phase diagrams are also included. AIME member, Henry H. Hausner, compiled the bibliography for Sylvania. To obtain a copy, mail $1 with your request to Sylvania Electric Products Inc., Chemical and Metallurgical div., Towanda, Pa.

► *Machining Ductile Irons* is the title of an 18-pp revised booklet just released by the Ductile Iron div., The International Nickel Co. Inc. The various machining and grinding techniques recommended for all grades of ductile iron—including turning, milling, drilling, broaching, gear hobbing and shaping, grinding, honing, lapping, and superfinishing—are included. Requests on company letterhead should be sent to The Ductile Iron div., The International Nickel Co. Inc., 67 Wall St., New York 5, N. Y.

► Allegheny Ludlum Steel Corp. is distributing a new booklet on stainless steel tubing. The 34-pp booklet gives details on sizes, grades, design data, corrosion resistance, and other information. More than 25 tables are included, plus photos and drawings. Ask for copies of *Allegheny Ludlum Stainless Steel Tubing,* from the Advertising dept., Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.

► *Superalloys by Vacuum Induction Melting* is a 36-pp brochure describing the production techniques and equipment used at Kelsey-Hayes Co.'s Metals div. plant in Hartford, N. Y. Property charts show the outstanding characteristics of alloys produced by the vacuum induction process as compared to conventional high-temperature alloys. To obtain copies, write: Dept. 17, Metals div., Kelsey-Hayes Co., Hartford, N. Y.

► *Designing for Pressed Brass and Nickel Silver Metal Powder Parts* is the title of a new 24 pp booklet prepared by The New Jersey Zinc Co. The first section of the booklet considers the powder metal process itself—compositions and properties of nonferrous alloys, commercial tolerances, practical design suggestions, and elements affecting costs. This is followed by an applications section which gives 27 case histories on product use..

Copies are available free from the Market Development div., The New

(Continued on page 370)

J&L STEEL

RESEARCH METALLURGISTS

Continuing growth of the J&L research and development program has created a number of openings for professional personnel, holding Ph.D., M.S., or B.S. degrees in metallurgy or a related scientific field. Projects underway or in prospect cover a diversity of subjects in physical and process metallurgy, all of course, related to the production of carbon and stainless steels, and all company supported. Because of this diversity, it is almost always possible to accommodate individual interests. The J&L Research Division is housed in the modern, air-conditioned, fully-equipped Graham Laboratory in suburban Pittsburgh. Attractive residential areas are close by. And progressive Pittsburgh offers many advantages, including full graduate programs at the University of Pittsburgh and Carnegie Institute of Technology for the man who wants to continue his professional education.

If you have these interests, we would like to hear from you, and will respect your confidence. Write.

J. A. Hill
Research and Development Department
JONES & LAUGHLIN STEEL CORPORATION
#3 Gateway Center
Pittsburgh 30, Pennsylvania

Coke pilot unit planned

A research facility for the experimental production of metallurgical coke from non-coking sub-bituminous coal will be built near Kemmerer, Wyo., and operated jointly by Food Machinery & Chemical Corp. (FMC) and U.S. Steel Corp. The test plant, scheduled for operation late this year, will have a capacity of 250 tons of coke per day. It will pursue an FMC-developed process, seeking to make use of Wyoming low-grade coal for FMC's elemental phosphorus plant in Pocatello, Idaho. Now this plant's coke requirements must come from east of the Mississippi river. U.S. Steel wants to test the Wyoming-grade coke in its blast furnaces.

Inco adds automated mill

A $12-million mill which permits centralized, and in some cases automatic control of crushing, grinding, flotation, and dewatering is The International Nickel Co. of Canada Ltd.'s latest facility.

The mill, located at the Co.'s Levack mine near Copper Cliff, Ontario, Canada, has a capacity of 6000 tons of ore per day.

In operation, crushed ore from the mine's No. 2 shaft is conveyed directly into a concrete silo-type bin, which has a capacity of 3000 tons. Two parallel conveyors feed the coarse ore to two 7-ft cone crushers, where it is reduced to −¾ in. The crushed ore is then conveyed to three large circular concrete bins. A special screening process removes the wood chips en route. The crushers, crusher oil pumps, screens, variable-speed ore feeders, and conveyors are all controlled by a central instrument panel where lights indicate what equipment is in service. Trouble in the unit sounds an alarm on the control panel and pinpoints the hold-up. Another recorder on the panel indicates the tonnage of ore being crushed.

The mill's two grinding units each consist of a 15-ft rod mill, a 14-ft ball mill, and two cone classifiers. Again, an instrument panel controls the operation, and weightometers measure the rate of ore flow into the grinding units. In the cone classifiers, the density of the overflow to flotation is measured and automatically controlled by radioactive isotope instruments which regulate the water addition to the classifiers.

The selective flotation process used produces nickel concentrate, copper concentrate, and tailings. Flotation process variables such as pulp density, temperature, and alkalinity are automatically controlled by a central panel. The flotation concentrates are dewatered in thickeners, followed by vacuum filters. The thickeners and filters are automatically controlled from an instrument panel on the filter floor. The thickener underflow pumps and filtrate pumps are remotely operated from this panel. More than 30 railway cars of nickel and copper concentrates are shipped each day to the Inco smelters at Copper Cliff and nearby Coniston.

German LD-AC plant

The first German LD-AC steel plant—for the treatment of high-phosphorous iron with powdered lime introduced into the oxygen stream—is to become a reality in the fall of 1961 with startup of two 110-ton furnaces. The Duisburg-Hamborn, works of August-Thyssen-Huette has placed an order for six such 110-ton furnaces utilizing the LD-AC process. DEMAG of Duisburg, Germany, has the order for the two units under construction, which will have a combined annual rated capacity of 750,000 tons. The furnace vessels are said to be of new design, with an inside diam. of 20 ft and a height of 31 ft.

• • •

DEMAG also has on order a 66-ton LD-AC vessel for Huettenwerk Salzgitter AG. It will go into operation this summer. A 44-ton LD-AC unit has also been ordered by Mannesmann Huettenwerke.

• • •

In The Netherlands, Koninklijke Nederlandsche Hoogovens en Staalfabricken n.V. Ijmuiden is replacing its two existing 66-ton LD vessels with three 110-ton LD units. The furnaces, scheduled for early 1961 delivery, are also being supplied by DEMAG.

Bethlehem adding oxygen

Plans to boost its Sparrows Point ingot capacity to 9 million tons annually were announced by Bethlehem Steel Co. This would be a 10 pct increase for the plant, already the world's largest.

Most of the increased tonnage will result from adapting the plant's No. 4 open hearth shop for oxygen. The shop contains seven furnaces rated at 375 tons each. At present two of the seven are using oxygen lances. To supply these and the other five, an oxygen plant with a daily capacity of 350 tons will be installed.

Wheeling investigates oxygen

Already changing over its Steubenville, Ohio, bessemer converters from air-blown to steam-and oxygen-blown, Wheeling Steel Corp. "is giving serious consideration to eventual replacement of these converters with an oxygen process. . . ." So reports Paul W. Koenemund, vice president in charge of operations at Wheeling.

Wheeling's current annual steel ingot capacity is 2,400,000 tons, and the changes to be completed by this fall (plus improvements in open-hearth practice) will increase its capacity to 2,500,000 tons. These alterations are designed to enable production of a low-nitrogen steel of open-hearth grade with a wider range of applications than air-blown steel, says Mr. Koenemund.

But, he cautions, "Before a final decision is reached regarding the replacement of bessemers at the Steubenville works, there are many problems involved in such long-range planning that must be solved."

REPORTER

Soviets probe Ethiopia

Ethiopia has signed an economic assistance pact with the Soviet Union, it has been reported in the *London Times*. The agreement calls for an extensive geological survey of the Country's minerals, plus the right to explore prospects of building a metallurgical works there.

Fuel cell demonstrated

An experimental fuel cell, which converts unpurified air and hydrogen gas directly into electric power, was demonstrated recently at Ionics Inc., Cambridge, Mass.

The process incorporates 1) a combination of a fuel electrode and an Ionics' membrane similar to those used in water desalting plants; 2) a platinum-coated electrode, known by the trade name *Tirrelloy;* and 3) a bromine-bromide acid solution in the cell which facilitates the utilization of air to produce power.

Extrusion clads metals

Cladding metals by extrusion offers many advantages, the Battelle Memorial Institute, developer of the process, finds. First, it permits close dimensional control over the cladded product; secondly, it permits a strong bond between the core and cladding material. A third advantage is that the cladding does not have to be the same contour as the core. In addition, the process permits cladding of shapes which cannot be clad by standard methods. To clad by the extrusion process, the core material is fed through a hollow mandrel converging upon a die. The mandrel is housed inside a chamber containing rams that are used to extrude the cladding material. The cladding material is forced through ports located in the chamber between the terminal end of the mandrel and the die. Thus, the core and cladding material pass through the die simultaneously. Both the core and the cladding are heated in the extrusion chamber. The process could be operated on a continuous basis, it is claimed.

The research was headed by A. M. Hall, chief of the Institute's Alloy Development div. Much of the Battelle work has involved aluminum-clad steel, although the process is also said to be applicable to cladding aluminum on copper and nickel and alloys of these metals.

The nature of the process, Hall said, makes it possible to produce integral bonds, simple mechanical bonds, and sheathing effects where an actual bond is not desired. The sheathing effect points up the possibility of cladding a core that has been coated with a nonmetallic material.

Selenium production rises

Production of selenium in 1959 totaled 799,097 lb—10 pct over 1958— so reports the US Bureau of Mines. The manufacture of dry-plate rectifiers accounted for approximately one-half of the selenium used during the year, the Bureau estimates. Use in the pigment, glass, ceramic, and metallurgical industries also showed gains.

Tellurium use up

Increasing demands of tellurium for thermoelectric devices contributed to a 1959 production of 196,400 lb, compared to 170,000 lb in 1958. Thermoelectric devices are being used for spot cooling in missile and space equipment. But they may also find application in electronics and instrumentation, and possibly in a commercial refrigerator requiring no moving parts. Some of the most promising thermoelectric cooling devices appear to be the intermetallic compounds, bismuth (and selenium) telluride and lead telluride.

Tellurium is also finding increased usage in the rubber, chemical, and ceramics fields. Total consumption for all needs in 1959 is estimated at 316,000 lb by the US Bureau of Mines.

New Zn-Ti alloy discussed

A new zinc-titanium alloy that offers greater resistance to creep and grain growth than any rolled zinc alloys developed to date was described by E. H. Klein during the American Zinc Institute's recent Annual Meeting. The new zinc alloy contains 0.8 pct Cu and 0.15 pct Ti, he reported. Developed by The New Jersey Zinc Co., the alloy is seen as useful for roofing products, electrical equipment, and metals goods in general.

Ta-W alloy used at 5200°F

A tantalum-tungsten alloy (90 pct Ta-10 pct W) is reported to remain strong and ductile from—200° to 5200°F. Developer of the alloy is Stauffer-Temescal of Richmond, Calif. The secret of its high temperature operation is the removal of metallic impurities such as iron, cobalt, and nickel. Temescal's electron beam furnace, besides reducing the contents of carbon, oxygen, and nitrogen, also reduces these metallic contaminants.

To obtain an alloy with such high temperature properties, Temescal uses cold-pressed bars of tantalum and tungsten powders. These are melted into crude 4-in. ingots, then remelted into high-purity ingots. A third melting cycle at a high rate gives 5-in. ingots which have the desired properties.

Metallurgists

The John Jay Hopkins Laboratory for Pure and Applied Science at General Dynamics' General Atomic Division in San Diego, California, is a modern center of research and development, where new ideas and techniques are vigorously pursued. Here, strong engineering and development activities are matched with broad basic theoretical and experimental research to create an ideal environment for productive efforts in the nuclear field.

Here, advanced work is underway on the High Temperature Gas-cooled Reactor (HTGR), which promises to be a major short cut to the nation's goal of economic nuclear power. The prototype HTGR plant will be completed in 1963 for Philadelphia Electric Company and High Temperature Reactor Development Associates, Inc.

Here, engineers and scientists work in a creative atmosphere on other advanced programs, including the MGCR gas-cooled reactor and closed-cycle gas turbine system for merchant ship propulsion . . . TRIGA reactors for training, research, and isotope production, which are now being installed on five continents . . . small nuclear power systems . . . test reactors . . . nuclear power for space vehicles . . . thermoelectricity . . . controlled thermonuclear reactions.

In the important field of materials research and development, immediate openings exist for experienced metallurgists, ceramists, and graphite specialists to investigate and solve the following types of problems: physical and mechanical properties of high-temperature materials and refractory compounds . . . high radiation and ultra high temperature-pressure effects on materials . . . reactor fuel element development and fabrication . . . fuel reprocessing . . . corrosion effects.

In addition to positions for Metallurgists, openings exist in varied research and development areas for Nuclear Engineers, Mathematicians-Programmers, and Experimental and Theoretical Physicists. Please address your letter of inquiry to Manager of Personnel, General Atomic, P.O. Box 608, Dept. 12, San Diego 12, California.

GENERAL DYNAMICS
GENERAL ATOMIC DIVISION

EDUCATION

(Continued from page 366)

Jersey Zinc Co., 160 Front St., New York 38, N. Y.

YALE RESEARCH

► The following research projects make up the 1959-1960 work being done at Hammond Metallurgical Laboratory, Yale University:

The Mechanism of the Martensite Transformation in Stainless Steel is the title of a study being undertaken by graduate student, J. F. Breedis, and W. D. Robertson, Chairman of the Dept. of Metallurgy. Morphology and crystallographic characteristics of the martensite transformation are being studied in large single crystals of iron-chromium-nickel alloys.

Structure of Ionic Solutions is the result of a reinvestigation and revision of the LiF-MgF_2 equilibrium diagram recently completed by graduate student, Cynthia Knight, and Dr. Robertson. They are now reconsidering a number of binary phase diagrams of ionic salts and, in particular, the structure of ionic solid solutions.

Alan Tetelman, another graduate student, and Dr. Robertson are probing the *Micromechanism of Fracture*. Structural mechanisms of fracture and embrittlement are being evaluated by detailed examination of the sites from which brittle fracture propagates in single crystals. At present, a quantitative X-ray study is being made of the effect of hydrogen on the iron lattice; this is to be followed by a study of embrittlement and fracture in high-purity, single iron crystals containing hydrogen.

Structure of Liquid Metals and Alloys is the topic under study by Gerald Abowitz and R. B. Gordon. Mr. Abowitz is a graduate student, while Dr. Gordon teaches the metal physics courses in the metallurgical department's curriculum. The men seek answers to the influence that structure of liquid metals and alloys exert on their physical properties. Observations of compressibilities and thermal expansion coefficients are being used to test an equation of state for liquid metals and to investigate the effects of the size, electronegativity, and valence of solute atoms on the structure of liquid alloys.

Graduate student, Allyn R. Von Neida, and Dr. Gordon are cooperating on a *Study of Conduction Electrons in Partially-Periodic Structures*. The behavior of conduction electrons in structures which are partially periodic is being investigated through observations of the Hall effect. The change in Hall coefficient that accompanies ordering in the alloy Cu_3Au has been studied as a function of the long-range order parameter and the size of antiphase domains.

Plasticity of Ionic Crystals is coming under scrutiny by Dr. Gordon and student, C. L. Bauer. A set of experiments providing a test of the theory of dislocation damping as applied to rock salt has already been completed. The results, which permit continuous observation of dislocation configurations, are being used in a study of the mechanisms of recovery and recrystallization after plastic deformation.

Dr. R. B. Gordon is also undertaking two individual research projects: *Application of Physical Acoustics to Metallurgical Problems*, and *Physical Properties of Intermetallic Compounds*.

His acoustics experiments are concerned with the use of high-frequency attenuation to observe the interaction between interstitial solute atoms and dislocations in metals. Models are being constructed which indicate the dependence of grain boundary energy on orientation in ionic crystals; these will be tested experimentally.

Graduate student, George Simkovich, and faculty member, J. B. Wagner, Jr., are collaborating on a study of the *Diffusion of Lead and Sulfur in Single Crystals of Lead Sulfide*. The diffusivity of lead in lead sulfide has been measured using radioactive lead. Single crystals having a stoichiometric composition and crystals with excess lead (n-type) or excess sulfur (p-type) have been prepared by equilibrating crystals with definite partial pressures of sulfur. Present results indicate that the predominant mechanism is diffusion via cation vacancies in p-type crystals.

Dr. Wagner is engaged in yet two other research projects. Martin Seltzer, graduate student, is working with him on *Diffusion in Semiconducting Materials as a Function of Anion Size*. The diffusion mechanism of radioactive lead in single crystals of lead selenide has been studied in the 400° to 800°C range. With the aid of doping experiments, the mechanism of lead in PbSe containing excess lead is inferred to be via an interstitial action. These studies are being extended to PbSe containing excess selenium.

The Oxidation of Metals in CO-CO_2 *Mixtures* is the project of F. Pettit and Dr. Wagner. For thick film oxidation of iron in CO-CO_2 mixtures, the rate determining step has been found to be the dissociation of CO_2 into adsorbed oxygen atoms or ions and CO. Temperature dependence of the oxidation rate shows discontinuities at magnetic transformation of the metallic substrate.

Metallurgy faculty member, C. N. J. Wagner, is also involved in three

(Continued on page 372)

letters to the editor

Rather!

Mr. G. C. Fear (January 1960, p. 37, paragraph three) should know that many of the more meticulous modern manufacturers meter molten metal most methodically.

Yours faithfully,
D. J. Grosse
Aluminum Laboratories Ltd.
Banbury, Oscon, England

Misstatement

I thank you very much for publishing our paper *Rimmed Steel Magnetic Sheets . . . How they were produced for the Proton Synchrotron*, in the February issue of JOURNAL OF METALS.

In carefully re-reading the article, I have detected a misstatement in the last part—the one concerning the results—which I had not discovered in the proofs you sent me for checking. This misstatement consists in the following: the results relative to Table II do not concern the normally cold-rolled sheets produced by Cornigliano, but the cold-rolled sheets produced, in various gages, in the same manner as for the proton synchrotron.

Hence, the phrase: "Table III shows the total magnetic losses of the normally-produced cold-rolled sheet for various gages at a frequency of 50 Hz and an induction of 10,000 gauss" under the subhead *Results*, on p. 157, should be so modified:

"Table III depicts the total magnetic losses, at a frequency of 50 Hz and at an induction of 10,000 gauss, for cold-rolled sheets, in various gages, produced in the same manner as sheets for the proton synchrotron."

I am very sorry for the misunderstanding which has caused this confusion, probably due to a not very clear original copy of the article. I also apologize that this misstatement was not detected during checking of the proofs.

I again thank you sincerely; kindest regards.

G. Odone
Research and Quality-Control-Supt.
Cornigliano SpA
Genova, Italy

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editorial

AFRICA

In past issues, JOURNAL OF METALS has taken its readers to many foreign lands to witness new plants and metallurgical developments. We have seen something of most of the European countries, the Soviet Union, Japan, China, India, and many others. Later this year we may turn our sights toward Latin America, but for the moment we find ourselves engrossed in one of the most fascinating continents of all AFRICA . . .a vast Continent with widely varying climate and geography . . . an area endowed with mineral riches in the form of gold, diamonds, copper, cobalt, uranium, manganese, chrome, iron phosphates, and bauxite . . . and a Continent with newly-discovered treasurers in petroleum.

For the future, perhaps one of Africa's most important assets lies in her tremendous hydroelectric potential. In the *Economic Survey of Africa since 1950,* published by the United Nations, we learn that, while, "Africa possesses less than 1 pct of the world's probable coal reserves . . . [this] . . . is offset by a large hydroelectric potential—about 40 pct of the world's total . . . [but] . . . less than 1 pct of Africa's hydro-power potential has been developed . . ." This hydroelectric potential, concentrated in west Africa in close proximity to iron, chrome, manganese, and bauxite, spells out new industries for Africa. In this issue we have concerned ourselves with aluminum, but this should not minimize the other metal potentials.

There is one factor which we have omitted in this glimpse into Africa's future, and certainly it is the most important factor of all . . people . . . 280 million of them . . . just beginning to feel their importance in the world. Natural resources are vast . . . yes . . . but it is now up to the people of Africa to decide what will be molded from them. Thus, as we look at Africa, whether from the standpoint of industrialization, or with an interest in social, economic, or political questions, it is the people with whom we are most concerned.

FWS

EDUCATION

(Continued from page 370)

investigations. With student, M. L. Joshi, he is undertaking an *X-ray Investigation of the Structure of Liquid Metals and Alloys.* Its prime objective is the determination of interatomic distances in liquid alloys. In order to reduce the theoretical difficulties of evaluating the structure of liquid alloys from X-ray data, binary systems in which the two components have similar scattering factors are being considered. The following alloy systems are being studied: Al-Mg, Al-Si, Cu-Ge, Cu-Zn, Cu-Ni, and Ag-Sn.

X-ray Study of Cold Work in Face-Centered Cubic Metals and Alloys at Low Temperatures is the title of a project undertaken by Dr. Wagner and student, R. P. I. Adler. They have found that cold working at low temperature introduces stacking faults in copper, silver, and gold (and their solid solutions with other elements), but not in aluminum. Faults were also found in cold-worked nickel. The studies are now being extended to alloys of silver (alpha-solid solution with fcc structure) and to the pure metals lead and palladium.

Dr. Wagner is involved in yet a third X-ray project: *X-ray Study of Cold Work in Body-Centered Cubic Metals.* Faulting on the {211} planes of bcc metals was found to be responsible for particle size broadening of X-ray powder pattern peaks of cold-worked iron and beta brass. These investigations are being continued on bulk specimens as a function of deformation. Recovery at different temperatures is being studied as a function of the annealing time.

► Plans to augment the Department of Metallurgy at Washington State University are announced by Dept. Chairman, S. A. Duran. Prof. Duran notes that there are presently four members in the department, but addition of two more metallurgists is expected by this fall. They will assume research duties on a half-time basis. D. E. Munson, D. R. Stiefbold, R. T. Wimber, and Prof. Duran now form the Dept.'s research nucleus. They are active in the following areas: kinetics of solid-state reactions in the presence of concurrent strain . . . high-temperature deformation mechanisms and kinetics . . . diffusion hardening kinetics in refractory metal systems . . . and thermoelectric behavior of matter. Prof. Duran reports that his department is ready to undertake fundamental and applied research in structure of solids . . . thermodynamics and phase equilibrium . . . deformation . . . kinetics of solid-state reactions . . . and physical properties.

RESEARCH METALLURGISTS

For Fundamental and Applied Research in Physical Metallurgy. Considerable latitude in choice of projects is provided and individual choice is encouraged. Areas of broad interests include high temperature alloys, cermets, magnetic materials, conductors, semi-conductors and abrasion resistant materials. Ideal spot for Ph.D.'s with several years experience and the desire to achieve success through personal initiative in research.

Write, giving details of educational background and prior work experience, to:

J. C. Schroeder
Employment Section C
Allis-Chalmers Mfg. Co.
Milwaukee 1, Wisconsin

personals

Eric R. Morgan has assumed the post of director of research for Jones & Laughlin Steel Corp. Dr. Morgan was formerly asst. director of research in charge of metallurgical research. Technical direction of J&L's research activities is the task Dr. Morgan has taken on. An active AIME member, the new director of research is Chairman of Pittsburgh section's Institute of Metals Group.

Frederick D. Delve is now supervisor of the Steel Works div., Metallurgical dept. of Jones & Laughlin's Pittsburgh works. A J&L employee since 1953, he was formerly a research engineer at J&L's Graham Laboratory.

Daniel R. Loughrey and **John F. Pollack** are among other J&L recent appointments. Mr. Loughrey has been appointed to the newly-created position of consultant to the superintendent, Pittsburgh works' Open Hearth dept. Previously, he was J&L's coordinator of steelmaking operations. Mr. Loughrey is now chairman of the National Open Hearth Steel Committee. Mr. Pollack was superintendent of the Pittsburgh works' Open Hearth dept. prior to his appointment as Mr. Loughrey's successor.

J. A. Pierce is now manager of technical sales for the Harbison-Walker Refractories Co. He has been a member of the technical sales department since 1951.

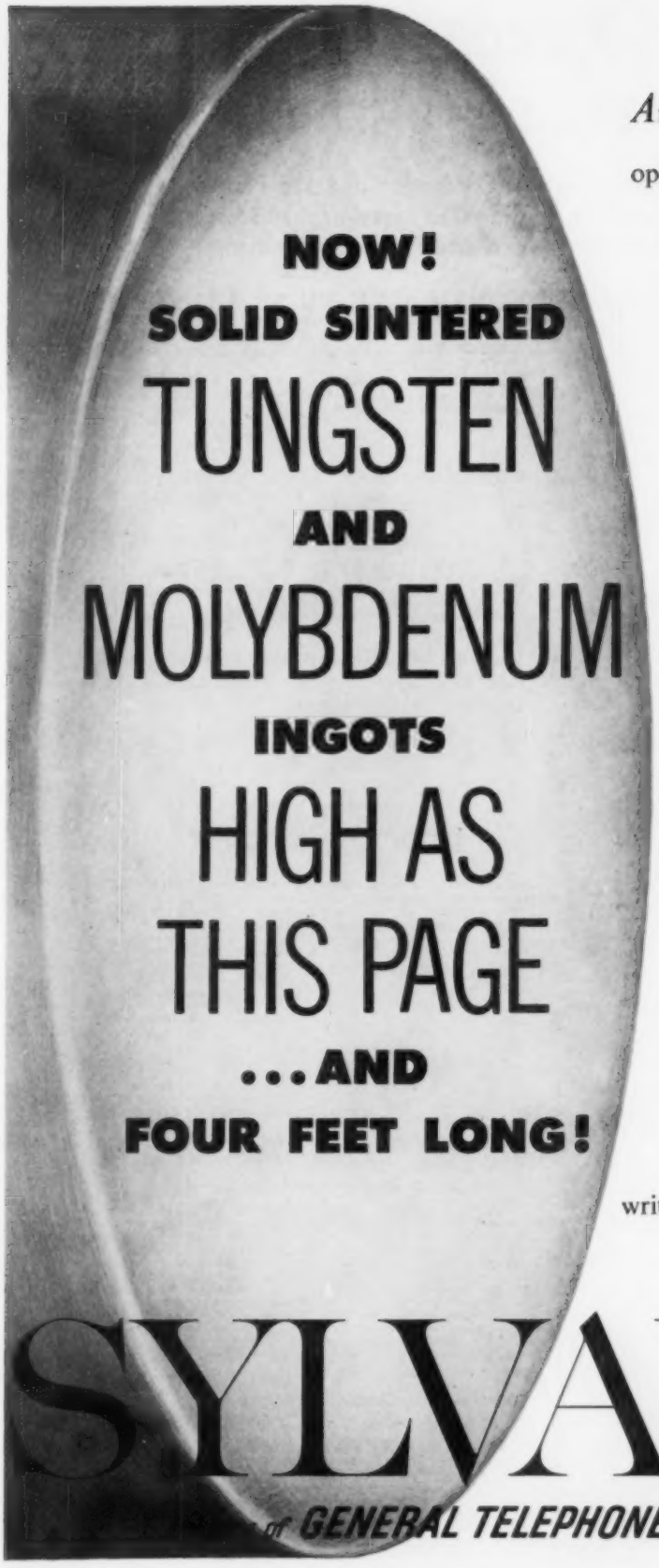
Russel B. Caples has retired his position as vice president of the Anaconda Co. He will continue to serve as a consultant to the company, however. Mr. Caples began his career with Anaconda in 1910. Among the distinctions he has achieved throughout the years is included the AIME's James Douglas Gold Medal for 1957 in recognition of Mr. Caples "distinguished achievement in extractive metallurgy, particularly in the electrowinning of zinc; and for outstanding success in stimulating the professional careers of many metallurgists."

Samuel B. Casey has left the Swindell-Dressler Corp. in order to assume the presidency of his family's construction business, the John F. Casey Co.

C. A. Crawford will be the technical director of the Investment Casting Institute in 1960, it has been reported. He assumed his position with the Institute following recent retirement from the International Nickel Co.

Henry W. Franz of the Western Mining div., Kennecott Copper

(Continued on page 418)



NOW!
SOLID SINTERED
TUNGSTEN
AND
MOLYBDENUM
INGOTS
HIGH AS THIS PAGE
...AND
FOUR FEET LONG!

Another first from Sylvania! A dramatic new isostatic pressing and sintering operation now makes it possible to supply missile and rocket makers with refractory metal ingots big enough for direct fabrication into their largest parts requirements.

By this process Sylvania can now produce 100% tungsten or molybdenum ingots up to 10" in diameter, 4 feet long! Various combinations of these elements are possible, too.

You can order ingots in a variety of sizes and shapes: rectangular, cylindrical or hollow cylinders. Special sizes and shapes are handled, too, on a special inquiry basis.

The fine grain structure achieved by this Sylvania process allows direct physical working of the material by rolling, forging or extruding.

In many cases, the smooth, clean, carbide-free surface eliminates the need for costly surface machining.

The process is relatively inexpensive, which means lower prices per pound for you over competitive processes.

If you're working with high-temperature metals requiring prefabricated ingots or consumable electrodes, Sylvania can help you. Call your Sylvania representative, or write Chemical & Metallurgical Division, Sylvania Electric Products Inc., Towanda, Pa.

SYLVANIA

of GENERAL TELEPHONE & ELECTRONICS

International Powder Metallurgy Conference Program

Sponsored by the Metal Powder Industries Federation and the Powder Metallurgy Committee, Institute of Metals Division, The Metallurgical Society, American Institute of Mining, Metallurgical and Petroleum Engineers.

BILTMORE HOTEL • NEW YORK CITY • JUNE 13-17, 1960

MONDAY, JUNE 13

9:00 am to 12:00 m—Ballroom

Welcoming:
Kempton H. Roll, Conference Co-chairman and Executive Secretary, Metal Powder Industries Federation; Fritz V. Lenel, Conference Co-Chairman and Professor of Metallurgical Engineering, Rensselaer Polytechnic Institute; Claus G. Goetzel, Program Chairman, Adjunct Professor of Metallurgical Engineering, and Senior Research Scientist, New York University.

Conference Keynote Address:

Dr. Paul Schwarzkopf, Honorary Conference Chairman and President, Metallwerk Plansee, Tyrol, Reutte, Austria: *Half a Century of Modern Powder Metallurgy.*

Symposium on Powder Metallurgy

Fundamentals and Theory

Chairman:
Leslie L. Seigle, Manager, Metallurgy Laboratory, General Telephone and Electronics Laboratories, Inc.

Co-Chairman:
George A. Geach, Head Physical Metallurgy Section, Associated Electrical Industries (Manchester), Ltd.

Theory of Sintering:

G. C. Kuczynski, University of Notre Dame

This is a review paper on the present status of the theory of sintering. As the details of the geometry of the contacts between individual particles are too complex to be treated theoretically, discussion is limited to simplified models such as spheres to spheres, spheres (or wires) to plates, etc. Experiments with such samples yielded fairly reliable confirmation of the theory proposed by the author. According to it, the first stage of sintering, characterized by formation of a neck between two particles, can be brought about by one or more of the following processes: viscous or plastic flow, evaporation and condensation, volume or surface diffusion. The well known relationships between the radii, x, of the neck, and, a, of the spheres, time t, and temperature T, can be described by one general equation

$$\frac{x^n}{a^m} = F(T)t$$

where $F(T)$ is a function of temperature only and

$n = 2$, $m = 1$ for viscous or plastic flow
$n = 3$, $m = 1$ for evaporation and condensation
$n = 5$, $m = 2$ for volume diffusion
$n = 7$, $m = 3$ for surface diffusion

The process of densification, or closure, of isolated pores was less extensively investigated. The evidence so far amassed indicates that, at least in metals, this process is closely related to Nabarro-Herring microcreep.

Most recent work on sintering of oxides and polymers will also be reviewed.

Sintering Behavior of Organic Materials:

G. A. Geach and A. A. Woolf, Associated Electrical Industries, (Manchester) Ltd., England

A number of mechanisms, including creep, are required to explain sintering of materials. The purpose of this work was to examine whether sintering and creep processes are necessarily related. A range of organic molecules, and one organo-metallic compound, whose sintering temperatures would be expected to be greater than room temperatures, were examined. Qualitative tests were made on powders and quantitative tests on pressed rods but in no instance was true sintering observed even at temperatures above 75 pct of their absolute melting points. However, the two substances which were examined, underwent creep at these temperatures. With sebacic acid, the logarithm of creep rate was inversely proportional to the absolute temperature. This indicated that a simple rate determining process was operative although this process was unable to produce sintering.

Sintering Mechanism of Titania:

G. Parravano, H. M. O'Bryan, Jr., and V. J. Lee, University of Michigan

The rate of sintering of titania single crystal microspheres has been studied in the temperature range 900 to 1200°C, in air and mixtures of $H_2 + H_2O$ of different compositions. The effect of sphere diameter has been investigated also. It has been found that the rate of neck growth between sintering spheres is considerably affected by the value of the ratio H_2:H_2O. An increase in the value of this ratio produced a faster sintering rate. This effect is explained in terms of the increased point defect concentration in titanium dioxide, since this concentration is controlled by the physiochemical equilibrium from the gas phase.

Sintering of Wire Compacts:

A. L. Pranatis and L. L. Seigle, General Telephone and Electronics Laboratories, Inc.

The influence of grain boundaries on the sintering rates of nickel, copper, and iron wire-wound compacts was studied. In iron compacts sintered in the alpha range, surface diffusion appears predominant and no grain boundary effect is therefore expected or evident. On the other hand, sintering of copper and of nickel compacts at temperatures close to their respective melting points apparently occurs by volume diffusion but with varying grain boundary effects. Neck growth in both materials appears entirely unaffected by the presence or absence of grain boundaries. Void shrinkage was found to be sharply inhibited in nickel samples from which grain boundaries had been deliberately eliminated, but no definite effect was noticed in copper, in apparent contradiction to previous results.

Interparticle Contacts in Sintering:

F. N. Rhines and R. T. DeHoff, University of Florida

It is predicted that the rate of densification in sintering should be proportional to the number of interparticle contacts in unit mass and that this number should remain constant during the first stage of sintering. Experimental evidence of the constancy of the number of contacts is offered. The relationship between number and the rate of densification is demonstrated for powders of fixed size with variable packing and powders of fixed packing with variable size. The number of contacts in a given mass is shown to be related inversely to the volume, as varied by vibration packing.

MONDAY, JUNE 13

12:15 pm—Fountain Court

Welcoming Luncheon

Speaker: Kempton H. Roll, Executive Secretary, Metal Powder Industries Federation

Subject: Powder Metallurgy and The Metal Powder Industry in The United States and Canada Today.

Please purchase tickets at Registration Desk

Symposium on Powder Metallurgy Fundamentals and Theory (Continued)

Chairman:
Leslie L. Seigle, Manager, Metallurgy Laboratory, General Telephone and Electronics Laboratories, Inc.

Co-Chairman:
to be announced

Microhardness Testing in Powder Metallurgy Research:

H. Bückle, Office National d'Etudes et de Recherches Aeronautiques, France

Two fundamentally different meanings of the term *microhardness* exist today: in certain quarters, microhardness testing is considered a method of routine inspection involving standard equipment and standard operating technique. This view, supported in the US by Lysaght, implies the allowance for unreliable results in the field of very small impressions or of delicate research problems. The technique based on this notion is unsuitable to powder metallurgical applications.

A more scientific definition lends to microhardness the character of a new method of scientific research. This view, supported by the author, implies an independent concept of microhardness involving suitably adapted apparatus, a special operating technique and a good knowledge of the so defined *microhardness*.

This paper deals with the particular applications of the microhardness method in powder metallurgical research problems. The special features of microhardness are described. It is shown that most typical applications are based on the principle of comparative studies of hardness variations, which are able to give valuable information about the structure of heterogeneous or porous bodies. The determination of the intrinsic hardness of minor phases is less reliable, but satisfactory results are obtained by the use of specially developed microhardness test plates, the application of which is described in the identification of single phases (hard metals) and of the non-destructive determination of thickness and nature of thin protective coatings.

Contribution to Liquid Phase Sintering:

F. Eisenkolb, Technische Hochschule, Dresden, Germany

The majority of investigations on sintering reported hitherto deal with processes that represent typical solid state reactions. Liquid phase sintering, however, is not only of importance theoretically, but also practically for it makes possible the production of new materials or those already known in a much simpler way. Eisenkolb and Kalning previously reported on the effect of a liquid phase on the results of model sintering tests. They demonstrated that a metal surface can be activated by fusing salts, thus accelerating the sintering process without increasing reaction. The object of further investigation was the behavior of metallic and non-metallic additions which melt in the sintering process when mixed with metal powders.

Sintering associated with the formation of a liquid phase that consists of metallic additions allied to and alloying with the base metal is comparable to fusion welding, whereas the sintering by use of metals differing substantially from the base metal and alloying with it only on the surface is similar to soldering. Conditions such as bonding or cementing, on the other hand, will result from the addition of non-metallic substances, e.g., to the fluxing agent type or corresponding to the slag particles present in commercial metals. Starting with these considerations tests were conducted, particularly on alloyed and unalloyed iron powders varying in their grain sizes and in their origin from different production processes. Powders of copper alloys, sulfides, and silicates delivering the required liquid phase at the sintering temperature applied were added to the iron powders described. The effects of these additions and of the sintering conditions on change in dimensions, porosity, and mechanical properties were determined. Samples containing additions of sulfides or silicates were tested for their applicability as friction or anti-friction materials.

A Plastic Flow Model of Hot Pressing:

J. D. McClelland, Atomics International

Hot pressing of powdered materials can be adequately described using a plastic flow model proposed by Mackenzie and Shuttleworth for sintering. The present derivation assumes that the principal driving force for the closing of pores is the applied hydrostatic pressure instead of the surface tension of the pores. This pressure term, when corrected for the density of the compact, can be substituted for the surface tension term in the original derivation. The resultant equations give the rate of densification of the material in terms of a yield point and a viscosity. The equations predict that an end point density will be reached which is dependent upon the applied pressure and the yield point of the material. This end point density will in general be less than the theoretical density.

The equations describe densification rates observed in beryllia when reasonable values of the yield point and viscosity are assumed. Pressure dependence of the end point density for several metal powders can be also satisfactorily explained. Preliminary data on the densification of tin under pressure at room temperature will be discussed in terms of this plastic flow model.

A Special Type of Activated Sintering:

J. Wulff, Massachusetts Institute of Technology

In studies of activated sintering carried out in this laboratory, it appears that the rate of densification of metal powder *A* can be markedly accelerated at a given temperature of such powder or powder compact contains a second metal *B*, whose coefficient of diffusion in *A* is higher than the self-diffusion coefficient of *A*. Since only small amounts of B in A are more often important from a practical standpoint, the coating of A by B provides the most effective mode of addition. In our own experimental work this has been accomplished by infiltration of tungsten powder compacts and sprayed coatings with a liquid solution of such metals as Ni, Fe, Co, Ti, etc. in zinc as well as Cr and others in copper, silver and lead. In the case of zinc, the carrier metal is readily evaporated before extensive sintering takes place. Similar results have been attained by employing co-reduced mixtures of oxides. In both techniques a density of greater than 95 pct of theoretical is achieved at temperatures appreciably below those required for the equivalent densification of pure tungsten.

High Density Sintering of Metal Powder Compacts:

M. Eudier, Metallurgie des Poudres, France

A brief review is made of the different conventional ways of obtaining high density parts, high temperature sintering, hot pressing, hot forging, rolling, extruding and drawing. Comparisons are made in order to explain the different practical results which are obtained and ways of increasing them. Other possibilities are then discussed and especially the use of ultra-fine powders, special atmospheres on thin films and intermediate liquid phases created by small additions as of phosphorus which can be eliminated afterwards. One of the examples is related to Bi_2Te_3 semiconductors.

Sintering of Very Fine Oxide Particles Produced by Calcination of Salts:

K. Iwase, T. Takada and T. Hayashi, Kyoto University, Japan

Electron microscopic and diffraction studies have been made of the mode of sintering of Fe_2O_3, Cr_2O_3, CoO and reduced Fe powders prepared by calcination of the respective metallic salts. When $(NH_4)_2Cr_2(SO_4)_4 24H_2O$ is heated below 750°C, the formation of Cr_2O_3 proceeds very slowly and a well developed large crystal is often obtained. When the salt is calcined at higher temperatures, large crystals are seldom obtained but rather an aggregate of very fine Cr_2O_3 particles. In general, the size of the individual particles increases as the calcining temperature increases. This is explained by the sintering of the particles during calcination. Electron diffraction studies indicate that the crystallographic axes of the individual oxide particles in an aggregate produced from a single crystal of salt are frequently aligned. This may be due to the similarity in the distribution of metal ions in the mother salt and in the oxide.

Sintering With a Chemical Reaction, as Applied to Uranium Monocarbide:

R. Caillat, A. Accary and I. Dubuisson, Commission à l'Energie Atomique, France

Uranium monocarbide is one of the most interesting fuels for nuclear power reactors. For reasons of reactor economy, the production of carbides of high density is of importance.

The paper concerns the preparation of a high density uranium monocarbide by two different methods. The first is a rather conventional one, based on the preparation of UC particles from uranium metal and graphite; the second method deals with the carbon reduction of UO_2.

Cold pressing and conventional sintering of UC particles does not result in a highly dense part, such as is necessary for nuclear reactors. It will be shown that by special and carefully controlled heating cycle, some interesting results can be obtained. Satisfactory results can be accomplished by hot pressing mixtures of uranium and graphite particles, and by the reaction going on between the two components during simultaneous application of heat and pressure. A tentative explanation of a seris of experimental data will be given.

TUESDAY, JUNE 14

9:00 am to 12:00 m—Ballroom

Symposium on Dispersion Strengthening

Chairman:
Frederick N. Rhines, Professor of Metallurgy, University of Florida

Co-Chairman:
Werner J. Leszynski, Special Ass't to the President, Schwarzkopf Development Corp.

The Role of Powder Metallurgy in Dispersion-Strengthened Alloy Development:

C. G. Goetzel and R. F. Bunshah, New York University

Alloys signified by a dispersed second phase in a metallic matrix tend to retain their strength at elevated temperatures longer and nearer the melting point than other types. They are of

considerable interest for applications in the high temperature and nuclear engineering fields.

Results of a recent survey of present and past work in this area have shown conclusively that powder metallurgy is the predominant process of producing dispersion strengthened alloys. Three distinctly different techniques for producing the dispersion are available. The second phase in all of them is incorporated in the powder which is consolidated by pressing, sintering and working.

The most versatile technique consists of mechanically mixing fine powders of the matrix metal and a nonmetallic substance. Matrix metals encompass copper, nickel, tungsten, molybdenum, stainless steel and many others. The most effective dispersoids belong to the group of refractory oxides including alumina, thoria, titania, and zirconia, but certain carbides and borides may also lead to interesting results.

The other two techniques are based on chemical reactions, chiefly with oxygen, of either the surfaces or the interior of the powder particles. The former generally applies to a metal, and SAP is the outstanding example. The latter requires an alloy powder containing a strongly oxygen-sensitive component. Copper-alumina and copper-silica, or nickel-alumina are important examples of the internal oxidation process as applied to powder. While an improved dispersion and smaller dispersoid size tend toward better physical properties, fewer alloy systems are suitable for dispersoid formation by chemical reaction, than by mixing the powdered ingredients.

A Theory of Dispersion Strengthening:

F. V. Lenel and G. S. Ansell, Rensselaer Polytechnic Institute

Dispersion-strengthening is explained by utilizing two methods of attack. The first, a theoretical approach, predicts the yielding and creep behavior of these alloys on the basis of dislocation theory. The second, an experimental approach, shows the variation of the yield and creep strength of these alloys with both the testing conditions and the structural parameters of these alloys.

The combination of these two approaches leads to a fundamental understanding of the mechanism involved in dispersion-strengthening. In particular, requirements can be set as to the dispersion morphology required for achieving dispersion-strengthening in an alloy system, based upon the fundamental constants of the alloy phases. These morphological requirements are applicable to dispersion-strengthened alloys in general. The additional requirement of high-temperature structural stability makes this treatment applicable to the SAP-Type alloys.

Dispersed Phase Hardening in Copper:

I. Jenkins, G. J. Catterall General Electric Co., Ltd., England.

It has been recognized for some time that considerable strengthening of a metallic structure can be achieved by introducing into it a dispersion of a second phase. The effect of the strengthening is related to the size of the individual precipitate particle and the spacing betwen neighboring particles. From the point of view of metallurgical stability however, it is also desirable that the second phase should be insoluble in the matrix and, in this respect, certain metal-metal oxide combinations hold great promise.

The present paper describes an investigation of such systems based on copper and oxides of either beryllium. aluminum, magnesium or silicon. Various methods will be described for achieving a satisfactory dispersion of the oxide in the metal and the effects of lattice coherency, particle size, and particle spacing on room temperature, physical and chemical properties will be discussed. High temperature creep and fatigue data will also be provided.

Properties of Nickel Containing Dispersed ThO_2:

D. K. Worn and S. F. Marton, Mond Nickel Co., Ltd., and Renold Chains Ltd., resp., England

The paper will describe part of a long-term investigation into the hardening of nickel and nickel-chromium base alloys by highly dispersed inert phases. It will be confined to nickel base materials containing a dispersion of thoria.

Preparation by two methods will be described—mechanical mixing of fine nickel and thoria powders, followed by compaction and extrusion, and mixing of nickel oxide with thorium nitrate solution, followed by ignition, reduction, compaction, and extrusion. The important characteristics of the raw materials used will be considered.

Data will be presented correlating room temperature mechanical properties, and elevated temperature stress-rupture properties, with the characteristics of the oxide dispersion. The work hardening and recrystallization behavior of cold drawn nickel-thoria alloys will also be described and discussed in relation to alloy structure.

Experiments on the effect of aging at temperatures up to 1400°C on the degree of dispersion will be reported. It will be shown that in the absence of harmful impurities, the nickel-thoria system shows a very high degree of stability at temperatures up to 1200°C, but that under certain conditions, marked agglomeration of the oxide phase can occur.

Internal Oxidation of Dilute Solutions of Ni and Cu for Dispersion-Strengthened Metal-Metal Oxide Alloys:

N. Komatsu, L. J. Bonis and N. J. Grant, Massachusetts Institute of Technology.

Internal oxidation of dilute solid solutions has been studied rather extensively. Most of this work has been done either with small diameter wires or thin strip. In applying internal oxidation as a means of producing dispersion hardened metal-metal oxide alloys, it is preferable to accomplish this with the alloy in fine powdered form. The purpose of this report is to discuss some of the problems associated with the internal oxidation process. These problems include powder size and shape, maximum solute content, oxide particle size as a function of temperature, time, distance of penetration, and solute type, etc. The effect of preferential grain boundary oxidation and the effect of such preferred oxidation on the resultant structure and properties are also considered.

Dispersion Strengthened Steels, Particularly Heat Resistant Steels:

Y. Imai and H. Hirotani, Tohoku University, Japan

The effect of additions of Al_2O_3, SiO_2 and MgO upon the hardness and creep-rupture strength of sintered iron, 13 pct and 18 pct ferritic steels and austenitic Ni-Cr steel was studied. The samples were made by powder metallurgical techniques using pre-alloyed powders and additions up to 15 pct by vol. of the oxides in the form of powder with a particle size as low at 1 μ. Changes in hardness as a function of annealing temperature and time are reported after cold working, as well as X-ray diffraction analysis of the annealed structure. Aluminum oxide was particularly effective in inhibiting recrystallization and increasing strength.

The Latest Developments in the S.A.P. Process:

E. A. Bloch and H. Hug, Aluminium-Industrie, A. G., Switzerland

For the practical manufacturing of S.A.P.—semis a heavy oxide-containing aluminum powder is used, the flakes of which are partly cold-welded. Each powder particle shows already dispersion hardening. Sintering in the strict sense, i.e., shrinking and consolidation of the compact does not take place in the case of S.A.P.; the oxides undergo, however, a transformation at a temperature ranging from 525 to 550°C. The powder particles will only weld together by hot-forming (hot upsetting and extruding). Electron micrographs of oxide replica show that the oxide is embedded in the metal groundmass in the form of platelets of 100-500 A thickness.

The influence of the manufacturing methods on the specific properties of S. A. P. has been the object of various investigations. There is no well-defined relation between the mechanical properties and the volume fraction of the oxide as the former depends to a great degree on the fineness of the dispersion of the oxide particles.

The workability of S.A.P. increases with decreasing oxide content. A material of for instance 7 pct oxide content allows the manufacture of rather complicated forms by hot and cold forming. Pressure-welding is possible below the melting point of aluminum.

1:30 to 5:30 pm—Ballroom

Symposium on Powder Metallurgy Technology and Methods

Chairman:

Henry H. Hausner, Consultant and Adjunct Professor, Polytechnic Institute of Brooklyn

Co-Chairman:

Michel Eudier, Managing Director, La Metallurgie des Poudres

Roll Forming of Metal Powders:

D. K. Pickens Chemetals Corp.

A brief review of the history of roll forming of metal powders is given. The fundamentals of the process are discussed in detail and experimental data on rolling various types of metal powders will be disclosed.

The paper deals mainly with the application of the powder rolling process for production purposes. Production equipment is described and the economy of the process is discussed. The characteristics of some metal powders best suited for roll forming will be analyzed. Application of the process to metal-ceramic combinations and to ceramic powders will also be described.

Hot Extrusion of Metal Powders:

P. Loewenstein, L. Aronin, and A. Geary, Nuclear Metals, Inc.

Powders can be made into solid useful bodies by two basic processes. In the first, pressure and temperature are applied to produce a dense body without extensive deformation. In the second, extensive deformation takes place in addition to the effects

of temperature and pressure. Powder rolling and extrusion are two examples of the latter. The hot extrusion process as applied to metal powders and to powder products will be discussed.

Several extrusion techniques can be used, which vary from the use of a dense sintered body to loose powders as the starting billet in the extrusion process. These will be discussed in detail and specific illustrations will be given.

Other variables of the extrusion process, such as temperature and reduction ratio and their effect on the properties of the resulting product, will de discussed.

A number of applications of extrusion to specific powder materials will be given; these are divided into three types. The first is metal powders mixed mechanically with other materials to obtain special properties. Examples of this type are dispersion type nuclear fuel elements such as uranium dioxide dispersed in an aluminum or stainless steel matrix, and cermets such as mixtures of aluminum and aluminum oxide and beryllium and beryllium oxide. Under this heading a method to produce extremely homogeneous bodies by the so-called *chip method* will be described.

The second type of powder extrusions are those using a dispersion hardening phase. The best known of these is the oxide dispersion strengthened aluminum (SAP) product. Similar principles have been applied to Mg, Ni, Cu, Fe and Mo, and will be discussed.

The third type uses pure metal or alloy powders and forms these into usable shapes. This may have advantages over conventional methods such as melting which may be difficult and result in large grain sizes, or because the powder extrusion method is convenient and allows great flexibility as well as high yields. Examples of this last type are extrusions of Be and of Cr.

In conclusion, the advantages of the powder extrusion method will be discussed and areas where further development is needed will be pointed out.

Hydrostatic Pressing of Metal Powders:

H. H. Hirsch and C. E. Van Buren, General Electric Co.

Particulate matter can be consolidated into shaped bodies by the application of pressure in a fluid to a powder charge retained and separated from the fluid by a flexible, non-porous membrane. This process, referred to as hydrostatic or isostatic pressing, can be modified in a number of important ways which affect the final product produced. For example, pressure can be applied slowly or rapidly, the charge can be de-aired or not, wax or other additives may be used or eliminated, the powder may be made to load into the flexible membrane densely or loosely, and so forth. These factors along with the effect of pressure, particle hardness and size distribution will be discussed in relation to their effects on the quality of the pressed bodies and subsequent processing. Experimental results obtained with a variety of materials will be included and the advantages and limitations of the process will be discussed. The type of equipment required for hydrostatic pressing will also be discussed.

Slip Casting of Metal Powders and Metal-Ceramic Combinations:

H. H. Hausner, Consultant, and A. Poster, Sylvania Electric Products, Inc.

The fundamentals of the slip casting process in ceramics are discussed in detail, as well as the variables of the process and the basic equipment. Mold design and properties of slip casting molds are described. The application of the known ceramic process to metal powders and metal powder mixtures is treated. The variables governing the metal powder slip casting process are analyzed and their effects on the green and sintered properties of slip cast metals are correlated. The paper deals, further, with the difference in the sintering of slip cast and pressure-compacted powders. Examples for slip casting of various types of metal powders are given. Production problems and the economy of the process are discussed. Slip casting of metal powders is not in competition with pressure compacting, but rather will widen the field of powder metallurgy for new applications.

Explosive Forming of Metal Powders:

R. A. Cooley, Propellex Div., Chromalloy Corp.

The first part deals with the general principles and the equipment for explosive metal forming, and its application to the compacting of metal powders. Explosive forming is compared with conventional compacting methods for powders, such as unidirectional pressing, roll-forming, and others.

The second part refers to most recent experimental work on explosive forming of various types of metal powders, the physical properties of powders which make them applicable to explosive forming, as well as an analysis of experimental data.

Lubricants for Powder Metallurgy Parts Manufacturing and their Influence on Properties:

R. S. Jamison and E. J. Geijer, Hoeganaes Sponge Iron Corp.

Prior to the briquetting of a metal powder part, a lubricant is usually mixed with the metal powder to minimize die wall friction.

This paper deals with the variations obtained in mixed, pressed and sintered properties of a sponge iron powder, with and without a graphite addition, when mixed with varying amounts of different stearates and other solid lubricants.

It has been found that particle size and bulk density of a certain lubricant greatly affects the apparent density, flow and compressibility of the mixed powder and also the die stripping pressure of the briquetted part.

Different kinds of lubricants do not only influence mixed and green properties, but partly depending on the varying residuals remaining after sintering, also influence sintered properties, such as strength and hardness.

Large Sintered Bodies and Parts:

F. Emley, Westinghouse Electric Corp.

The size barrier in powder metallurgy has been hurdled in recent years, both for conventional shaped parts and in the pressing of intermediate bodies. The various powder compaction processes will be reviewed in regard to the largest sizes of parts which are made commercially by each technique. Limitations and potential sizes which could be produced by each process will be discussed. The present status of processes for continuous compaction will be presented with a discussion of potential applications.

TUESDAY, JUNE 14

7:30 pm—Banquet-Ballroom

Master of Ceremonies—George A. Roberts, Vice President, Vanadium—Alloys Steel Co., and President, Metal Powder Industries Federation.

Principal Guest Speaker—Dr.Charles E. Reed, General Manager, Chemical and Metallurgical Division, General Electric Co.

WEDNESDAY, JUNE 15

9:00 am to 12:00 m—Ballroom

Symposium on Powder Metallurgy Alloys, Materials, and Applications

Chairman:

Carl G. Johnson, Professor of Mechanical Engineering, Metallurgy Section Head, Worcester Polytechnic Institute, and Vice-President, The Presmet Corp., Worcester, Mass.

Co-Chairman:

Peter Evans, Department of Chemical Engineering, Fuel Technology and Metallurgy, The Manchester, College of Science and Technology, Manchester, England

Refractory Powder Metallurgy Alloys and Products:

H. W. Highriter, Fansteel Metallurgical Corp.

For practically the first half of this century the refractory metals W, Mo, Ta, (except for the application of tantalum for chemical equipment) were used only in applications such as incandescent filaments, electronic tube parts, X-ray targets, etc., in which high melting point, and low vapor pressure were the major requirements. The parts required were small and the metals were used in pure form.

In the decade just ended these electronic applications continue, but new demands have arisen as a result of the need for structural parts of missiles, supersonic vehicles and spacecraft that will possess maximum mechanical properties at high ambient temperatures. These structural applications have led to the development of numerous alloys of the refractory metals as well as to the use of production techniques capable of producing mill shapes and parts larger than heretofore required.

The principal alloys and their properties and applications are discussed.

Recent Investigations of High Temperature Alloys of Molybdenum and Tungsten:

H. Braun and K. Sedlatschek, Metallwerk Plansee, Austria

High melting alloys of molybdenum and tungsten with transition metals of the group IVa-VIa of the periodic table and with rhenium are now being investigated in a large number of laboratories. At the Metallwerk Plansee, the workability of sintered and arc-melted tungsten-columbium and tungsten-tantalum alloys have been examined as well as the following properties of alloys with compositions across the entire binary systems: density, hardness

at room temperature and elevated temperatures, specific electric resistivity, thermoelectric force, hydridability, corrosion resistance against acids and alkali. Alloys of molybdenum with 0 to 100 pct columbium and tantalum have been technologically surveyed: their density, hardness, specific electrial resistivity, thermoelectric force and corrosion resistance have been examined and their workability evaluated. Sintered alloys of tungsten with up to 30 pct rhenium were examined in the cold or hot rolled condition: their strength, ductility, recrystallization behaviour and thermoelectric force against tungsten have been evaluated. The systems tungsten-vanadium and tungsten-hafnium were examined metallographically and by X-Ray means and their constitutional diagrams established.

Heat-Resisting Materials by Powder Metallurgy:

G. T. Poyner, V. A. Tracey, and J. F. Watkinson, BSA Research Center, England

The properties obtained on material produced by vacuum sintering certain nickel-chromium-cobalt type pre-alloyed powders are given. The results show that the stress-rupture properties obtained on sintered material can compare favorably with the stress-rupture properties of wrought material of the same composition, although the hot-fatigue and cold-impact properties are generally lower. The stress-rupture properties of one particular compostition were found to be variable, but in some instances notably improved properties over the wrought alloy were observed. This enhanced performance was attributed to the pick-up of beneficial elements during melting, such as boron. Later, controlled deliberate additions of boron and zirconium were made.

The influence of additions of tungsten or molybdenum on the stress-rupture properties of a base alloy containing nickel, 20 pct Co and 16 pct Cr (with aluminum and titanium) was examined. It was found that when these elements were present the optimum stress-rupture properties were associated with additions of 2½ pct Mo and 7½ pct W respectively. The effects of titanium and aluminum contents were investigated on a similar base alloy with a molybdenum content of 5 pct. The best stress-rupture properties were obtained with high aluminum-plus-titanium contents, and with high titanium-to-aluminum ratios. These factors are being studied in greater detail.

From this systematic research a proprietary alloy *Cosint 1000* has been developed, which has noteworthy properties. Its nominal composition (weight-per cent) is 20 Co, 16 Cr, 5.5 W, 2.5 Mo, 5.5 Al, 2.5 Ti, 0.02 B, 0.3 Zr, Balance Ni. Further details regarding sintering conditions and performance are given in the paper. It is concluded that heat-resisting components prepared from suitable pre-alloyed powders can possess strength properties comparable with those of some of the best known wrought alloys: and have other advantages such as small, uniform grain-size and high resistance to grain-coarsening in final hot-working operations.

Titanium and Zirconium Powder Metallurgy:

A. D. Schwope, Clevite Corp.

The application of powder metallurgy techniques to the manufacture of titanium and zirconium base alloy components offers a potentially economical method of fabrication. Good material utilization coupled with a minimum amount of machining and working are particularly important in the reactive metals. The effect of processing variables on the mechanical and physical properties are described. If a double pressing and sintering operation is used, properties comparable to those found in melted and wrought alloys can be obtained. Strengthening effects at high temperatures of dispersed phases and fibers are reviewed. Present and potential applications of powder products are described.

Influence of Processing and Design Variables on Properties of Sintered WC-Co alloys:

J. Gurland, Brown University

This paper is concerned with a number of production and design variables which affect the properties of sintered carbides. The systematic study includes three WC-Co compositions with, respectively, 6, 10, and 15 pct by weight of cobalt, and three commonly measured properties of sintered compacts, namely density, hardness and transverse rupture strength. Practical results will include production variables i.e., mixing procedures, compacting pressure including pressureless compacting by vibration, time and temperature of sintering, infiltration, and design variables influencing properties are included in this study.

The theoretical part of the paper rationalizes the observed behavior in terms of the sintering mechanism and the mechanics of brittle materials.

Effects of Spark Erosion on some Cemented Carbides:

Y. Matsuyama and T. Fukazu, Toshiba Tungoloy Co. Ltd., Japan

When a single point cutting tool of grade *S* cemented carbide is spark-erode-sharpened at its cutting edge, its cutting life is said to be improved. The present study was carried out to explain this fact. Cemented carbide tips of grade *S* were sharpened by spark-erosion with the Wickman spark erode machine and by the use of a metal bonded diamond grinding wheel, grade 150. Cutting tool life was measured and it will be shown that the spark-erode-sharpened tool developed very much longer tool life than the tool sharpened with the diamond wheel.

Surface hardness is compared, as well as X-ray diffraction characteristics, to demonstrate that the surface states or structures are somewhat different as a result of sharpening by each method.

From the results brought out by this study it can be said the amount of solid solution of WC and TiC in the surface layer is increased by the spark erosion technique of sharpening. The mechanism by which this change in concentration of WC and TiC occurs is suggested by the authors.

1:30 to 5:30 pm—Ballroom

Symposium on Powder Metallurgy, Alloys, Materials, and Applications (Continued)

Chairman:

Carl G. Johnson, Professor of Mechanical Engineering, Metallurgy Section Head, Worcester Polytechnic Institute, and Vice-President, The Presmet Corp., Worcester, Mass.

Co-Chairman:

Peter Evans, Department of Chemical Engineering, Fuel Technology and Metallurgy, The Manchester College of Science and Technology, Manchester, England

Nickel-Coated Composite Powders—Preparation and Properties:

B. Meddings, W. Kunda and V. N. Mackiw, Sherritt Gordon Mines Ltd., Canada

A brief description of the Sherritt process for the reduction of nickel from solution is given, indicating how this technique has been extended to the nickel coating of powders. The surface activation required for non-catalytic powders is discussed and the range of the present technique is outlined. The general physical and chemical requirements of the process are specified and discussed. Several of the more interesting composite powders are described in detail and photomicrographs are shown. The physical and chemical factors influencing the preparation of these composite powders and the properties of the prepared powders are described and discussed. Possible fields of application for these materials are mentioned.

Shrinkage Compensation Through Alloying:

H. Silbereisen, Mannesmann-Pulvermetall G.m.b.H., Germany.

In the construction of pressing tools, especially for complicated parts, it is always difficult to pre-determine the correct dimensions of the dies and punches. Often it is necessary that these dimensions be fixed empirically whereas the linear contraction during sintering is not only dependent on the pressure, sintering temperature and other factors which can be determined, but also on the shape of the compact. This requires in many cases the construction of the dies before starting with the actual production.

The known volume increase through addition of copper to iron powder was tested in a series of experiments. It was found that it was possible to compensate for the shrinkage through correct additions of copper, i.e. neither an increase nor a decrease in volume occurs. Through control of this method one can match the size of the die blueprint tolerances, and can obtain a compact which possesses to a large extent the desired final dimensions.

The cited pre-determined shrinkage dimension means facilitating considerably the construction of the tools because the blueprint can always be adapted without preliminary experiments. In individual cases it is merely necessary to vary the copper content in order to arrive at the desired dimensions of the compact. This method is applicable as well to pressed and sintered parts as to parts which are to be sized. If the relationship between copper content and dimensions before and after sintering, respectively, are correctly adjusted, it is even possible to use a tool of fixed dimensions for pressing, re-pressing, and sizing.

Behavior of Lubricant in Porous Bearings:

J. Heuberger, AB Glissa, Sweden

The main difference between classic oiled bearing and a porous oil-impregnated *self lubricating* bearing is that in the porous self-lubricating bearing the oil does not only stream into the clearance, but also into the inner parts of the sinter materials system of pores. Very little is known about these inner oil currents in self-lubricating bearings.

The oil current, caused by the hydrodynamic pressure in the bearing, can be seen through measurements of pressure. The oil current resulting from the porous materials elastic deformation in the starting moment of the bearing will be demonstrated. By investigating the currents caused by capillary forces it has been proved that the speed of the current is comparatively small. The dependence of oil current speed upon temperature and viscosity of the oil will be proved. The consequences of these results for the oil impregnated porous bearing will be established.

Recent Trends in European Metal Powder Parts Manufacture:

S. Hulthen, Hoganas-Billesholms Aktiebolag, Sweden.

The average annual increase of iron powder consumption for sintered bearings and parts in Europe during the last 5 yrs can be estimated at between 25 and 35 pct. Requirements regarding physicals and tolerance specifications are more severe than is the case in the US. Part of the industry, especially during the last 3 yrs, has developed a range of parts with high physicals, which however can be regarded as highly qualified blanks intended for further machining rather than as finished sintered parts. Efficient presses as well as continuous and semi-continuous furnaces for temperatures up to 1300°C have facilitated the manufacture of sintered parts with high physicals.

More recently much work has been devoted to the problem of manufacturing sintered parts with properties equalling those of ordinary forgings. This last mentioned development has however not yet advanced to the stage of regular production.

An Exploratory Investigation of Pre-alloyed Powders of Aluminum:

S. G. Roberts, Kaiser Aluminum and Chemical Corp.

A report of research in progress is given on the utilization of alloy powders instead of conventionally cast ingots in the production of wrought aluminum base alloys. An exploratory alloy survey was conducted to determine the mechanical and metallurgical characteristics of laboratory scale extrusions made from atomized prealloyed powders. The alloys investigated were based on the common aluminum alloy systems and ranged in composition from current commercial alloys to highly alloyed materials in which the alloying additions were greatly in excess of the levels feasible with current commercial practices for wrought alloy production. The tensile properties and metallurgical characteristics of the small extrusions are given and the potential advantages of extending the current composition limits of useful alloys of aluminum by powder metallurgy techniques are discussed.

Powder Metallurgy Provides Friction Material Work Horse:

C. S. Batchelor, Raybestos Div., Raybestos-Manhattan, Inc.

In the early '30's, steering clutches and aircraft brakes were being required to operate well above 800°F, which burned the conventional abestos-resin friction material to destruction. Powder metallurgy supplied a material with a copper-tin matrix in which were mechanically occluded high percentages of inorganics and insoluble metal. This solved the problem of the moment, but, soon, greater energy absorptions without commensurate increase in brake or clutch size made applications marginal, and iron base and later cerametallic friction materials were developed. All of these materials are in use today but increased service requirements and broad new fields of application such as heavy duty truck brakes, aircraft brakes, brakes for both passenger and freight cars, missile components and special passenger car brakes such as pursuit cars demand new physical shapes and advanced thinking in metallurgy.

Presently, iron-graphite combinations, cerametallics and certain austenitic compounds are showing considerable promise in the tough spots. The present uses, with their virtues and limitations will be discussed with some formulation and processing data. These materials all have commercial applications but are in primitive stages, with great probability of continued improvement and further exploitation.

Beryllium with its low gravity, high modulus of elasticity, high specific heat and high conductivity has tremendous potential for the future, particularly, for aircraft brakes. The difficult powder metallurgy problems of beryllium are gradually being overcome which will unlock another advancement in heat sink brakes.

The future of powder metallurgy friction development lies along several avenues all of which give promise of new advancements in specific fields.

Recent Advances in the Powder Metallurgy of Beryllium:

W. W. Beaver, The Brush Beryllium Co.

New processes now being employed or evaluated for consolidation of beryllium powder in both developmental and production operations will be reviewed. The influence of processing methods and the effects of grain size and purity on the mechanical and thermal properties will be discussed. New products for nucleonic, aerodynamic, and electronic applications will be described.

Thursday and Friday, June 16 and 17

PLANT TOURS

A series of five plant tours covering nine companies have been arranged for registered conference attendants. Transportation by chartered bus will be provided. Purchase tour tickets at the Registration Desk on the 19th floor. Departure times and other information will be shown on the tickets. Buses will leave promptly on schedule from the Vanderbilt Avenue entrance to the Biltmore Hotel.

TOUR NO. 1

Hoeganaes Sponge Iron Corporation, Riverton, New Jersey

This plant is one of the world's largest producers of iron powder designed for powder metallurgy consumption. The plant was constructed in 1952 and employs plant engineering techniques that achieve fully automatic processing beginning with three raw materials: magnetite, coke, and limestone.

F. J. Stokes Corporation, Philadelphia, Pennsylvania

A wide range of compacting presses for the powder metallurgy industry and other fields qualify Stokes as a leading producer of mechanical and hydraulic presses. In addition, this concern manufactures plastic molding presses, vacuum furnaces, and allied equipment.

TOUR NO. 2

Presmet Corporation, Worcester, Massachusetts

Presmet is a medium size custom fabricator specializing primarily in sintered structural parts. This firm has complete powder metallurgy processing facilities including their own tool shop and extensive machinery and heat treating facilities. They utilize a wide variety of both ferrous and non-ferrous powders.

TOUR NO. 3

Lionel Corporation, Irvington, New Jersey

Lionel is a large manufacturer of toy trains, fishing reels, and other products that utilize powder metallurgy parts in their assembly. In-plant facilities include a complete, modern powder metallurgy parts manufacturing department and powder metallurgy laboratory.

Alan Wood Steel Company, Conshohocken, Pennsylvania

Alan Wood has developed a unique new iron powder process—the H-Iron Direct Reduction Process. It employs a low-temperature, high-pressure system to reduce magnetite to iron powder. Control laboratories and plant facilities will be shown.

TOUR NO. 4

Pitney-Bowes, Inc., Stamford, Connecticut

Pitney-Bowes is a major manufacturer of addressing machines, postage meters, scales, etc. They have a modern in-plant powder metallurgy operation that is devoted to fabricating components for this equipment. Although they produce self-lubricating bearings, their major emphasis is on ferrous materials and includes the production of both medium and high-density parts.

Sintercast Division, Chromalloy Corp., Yonkers, New York

Sintercast specializes in several of the more unique phases of powder metallurgy. Some of their current efforts, which are mainly in the development or pilot plant stages, include: powder rolling and extrusion, machinable carbides, and nuclear control materials.

TOUR NO. 5

Adamas Carbide Corporation, Kenilworth, New Jersey

Adamas is a manufacturer of cemented carbides in both the semi-finished and finished condition. Some of the finished shapes include tool bits, rock cutters, and drawing dies. In addition they produce their own carbide and cobalt powders, and have complete powder testing facilities.

American Metal Climax, Inc., Carteret, New Jersey

A subsidiary of American Metal Climax, United States Metals Refining Co., is one of the major manufacturers of non-ferrous powders. Their principal products are electrolytic copper powder and atomized tin and solder powders. In addition to production operations, they will show their research facilities for metal powders.

TRANSACTIONS Papers Accepted to May 1, 1960

Constitution of Fe-C-Mo Alloys Containing 0.05 Pct-1.3 Pct C and 0.03 Pct-6.0 Pct Mo, by R. F. Campbell, S. H. Reynolds, L. W. Ballard, and K. G. Carroll (IMD)

The Precipitation of Carbon from α-Iron I. Electronmicroscopic Study, by R. H. Doremus and E. F. Koch (IMD)

The Precipitation of Carbon from α-Iron II. Kinetics, by R. H. Doremus (IMD)

Stress Induced Twin Boundary Motion in AuCd β' and β'' Alloys, by H. K. Birnbaum and T. A. Read (IMD)

A Basket-Cathode Electrolytic Cell for the Production of Titanium Metal, by W. R. Opie and O. W. Moles (EMD)

The Solubility of Lead in Liquid Iron, by Arthur E. Lord and Norman A. Parlee (ISD)

Relationship Between the μ-Phase and the σ-Phase in the Mo-Mn-Co System, by B. N. Das and Paul A. Beck (IMD)

Environmental Effects on the Mechanical Properties of Ionic Solids with Particular Reference to the Joffe Effect, by R. J. Stokes, T. L. Johnston, and C. H. Li (IMD)

The Absorption and Effusion of Hydrogen in α-Iron, by D. C. Carmichael, J. R. Hornaday, A. E. Morris, and N. A. Parlee (IMD)

Structures and Properties of Titanium-Rich Titanium-Nickel Alloys, by J. W. Barton, G. R. Purdy, R. Taggart, and J. Gordon Parr (IMD)

Kinetics of Grain Boundary Migration in High Purity Lead Containing Very Small Additions of Silver and of Gold, by J. W. Rutter and K. T. Aust (IMD)

Identification of Chi and Sigma Phases in Stainless Steel with the Electron Probe Microanalyzer, by L. S. Birks, J. M. Siomkajlo, and P. K. Koh (IMD)

The Aging Characteristics of a Ti-13V-11Cr-4Al Alloy, by R. A. Rawe, J. M. Dupuoy, and M. B. Bever (IMD)

Gaseous Reduction of Fine Iron Ores in the Fluidized State, by S. Y. Ezz (ISD)

Phase Relationships in the Systems Fe-Pb-Ni, Fe-Ni-C (SAT.) and Fe-Pb-Ni-C; 1300°-1550°C," by K. O. Miller and J. F. Elliott (ISD-EMD)

Influence of Processing Variables on the Properties of Nickel—Al_2O_3 Alloys, by Laszlo, J. Bonis and Nicholas J. Grant (IMD)

Dislocations in Deformed Single Crystals of α-Brass Part II—Pile Ups, by J. D. Meakin and H. G. F. Wilsdorf (IMD)

Rare Earth Compounds with the $MgCu_2$ Structure, by J. H. Wernick and S. Geller (IMD)

High-Temperature Short-Time Creep of Graphite, by H. E. Martens, L. D. Jaffe, and D. D. Button (IMD)

The Carbon-Oxygen Equilibria in Liquid Iron, by Tasuku Fuwa and John Chipman (ISD)

The Effect of Oxide Microstructure on the Oxidation Kinetics of Cu-Ni-Mg Alloys, by J. A. Sartell, S. H. Bendel, and C. H. Li (IMD)

Rates of Growth of Cementite in Hypereutectoid Steels, by R. W. Heckel and H. W. Paxton (IMD)

The Evolution of Textures in FCC Metals, Part I—Alloys of Copper with Germanium and Tin, by Y. C. Liu and R. H. Richman (IMD)

Deformation Modes of Zirconium at 77°K, 575°K, and 1075°K, by E. J. Rapperport and C. S. Hartley (IMD)

Precipitation Processes in Copper-Rich Copper-Iron Alloys, by A. Boltax (IMD)

Cobalt-Rich Ternary Alloys with Tin and Carbon, by L. J. Huetter, H. H. Stadelmaier, and W. K. Hardy (IMD)

Growth of Chromium Coatings from Liquid Metallic Solutions, by S. T. Wlodek and John Wulff (IMD)

Dispersion-Hardening in Binary Titanium-Copper Alloys, by D. N. Williams, R. A. Wood, H. R. Ogden, and R. I. Jaffee (IMD)

High Temperature Slip in Tungsten, by Sam Leber and J. W. Pugh (IMD)

Measurement of Kirkendall Effect in the Iron-Chromium System, by H. W. Paxton and E. J. Pasierb (IMD)

Join the Metal Man's Society Now!

The Metallurgical Society of AIME
29 West 39th Street
New York 18, New York

Gentlemen:

I am interested in joining The Metallurgical Society. Please send further information and an application for membership.

Name _____

Address _____

Qualified individuals belong to The Metallurgical Society of AIME to insure professional development and identification through active support of the metal man's society.

Maximum service on a basis of technical specialties is achieved through divisional organization. The Institute of Metals Division serves those engaged in developing, economically producing, and applying new alloys.

The importance of Iron and Steel Division activities is reflected in the active support of these activities by men in all phases of the ferrous metals field. A number of ISD meetings have become nationally famous.

The Extractive Metallurgy Division consists of men who work in extraction, smelting, and refining of nonferrous metals. Here, as throughout the Society, a balanced program results in professional growth through membership.

METALGRAMS

UNION CARBIDE METALS

. . . news about "Electromet" ferroalloys and metals

MAY, 1960

NEW EXOTHERMIC CHROMIUM SAVINGS -- Open-hearth melters using an exothermic ferrochrome ladle practice can save from 50 to 60 cents per ton by using new "Chromtemp" ferrochrome 25-6. The silicon content of the alloy (6.25 lbs. per can) saves the steelmaker money by replacing separate ferrosilicon additions required with straight chromium exothermic alloys. Your Union Carbide Metals representative will be glad to give you further information.

* * *

EXOTHERMIC WITH MORE HEAT -- Closer control of large open-hearth ladle additions can now be obtained with the greater exothermicity of "Chromtemp" exothermic ferrochrome and "Mantemp" exothermic ferromanganese. The improved reaction promotes greater stirring, minimizes segregation, and dissolves the alloy faster. The result is better control of alloy analyses, resulting in fewer off-grade heats. Specification sheets for these alloys may be obtained by requesting F-20,124 and F-20,125.

* * *

LESS GAS THAN EVER -- Producers of vacuum-melted steels and high-temperature alloys have improved their melting operations with new "Elchrome" VG electrolytic chromium. Having less than 0.06 per cent oxygen and extremely low hydrogen and nitrogen contents, this high-purity vacuum-grade chromium has the lowest gas content commercially available. As a result, it's easier to maintain a vacuum and there's less spattering and boiling in the bath. Ask your Union Carbide Metals representative for the analysis of this improved chromium metal.

* * *

EYES ON PHILADELPHIA -- Foundrymen interested in the latest uses of ferroalloys to produce better castings will want to visit Union Carbide Metals' extensive exhibit at the 64th AFS Castings Congress and Exposition, May 9-13, in Philadelphia. The Union Carbide Metals' exhibit covers 41 foundry alloys. Featured are alloys that give better properties to cast iron, allow more efficient production of ductile iron, cut costs of steel, and give greater purity to aluminum. Experienced UCM metallurgists and engineers will be on hand to provide on-the-spot assistance. You are cordially invited to visit the exhibit and talk to UCM personnel. See us at booth No. 1214.

* * *

GASES ARE FLUSHED OUT -- A new alloy -- magnesium-calcium-silicon -- has been used successfully to flush out gases in high-alloy heats melted in the induction furnace. The alloy is added to the ladle and produces a vigorous flushing action. One producer reduced his rejection rate caused by gas imperfections from 30 to 5 per cent on a 35 per cent nickel, 15 per cent chromium casting. For the case history, write for the article, "Rejections Cut With New Alloy," in the Winter 1960 issue of UNION CARBIDE METALS REVIEW or contact your UCM representative for further details.

* * *

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COLUMBIUM METALLURGY SYMPOSIUM

Sponsored by the Hudson-Mohawk Section of AIME
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The Metallurgical Society of AIME

JUNE 9-10, 1960

Hotel Sagamore, Bolton Landing, Lake George, New York

THURSDAY, JUNE 9, 1960

Fabrication 8:30-11:30 am

Chairmen:
R. G. Frank, General Electric Co., Cincinnati, Ohio
A. B. Michaels, Fansteel Metallurgical Corp., North Chicago, Ill.

Solid Phase Bonding of Columbium, S. Paprocki, Battelle Memorial Institute, Columbus, Ohio.

Evaluation of Forming Characteristics of Columbium Alloys: R. T. Torgerson, Boeing Airplane Co., Seattle, Wash.

Influence of Carbon Additions on the Workability and Mechanical Properties of Columbium: R. T. Begley and A. I. Lewis, Westinghouse Electric Corp., Pittsburgh, Pa.

Fabrication of Columbium Alloy Castings at Low Temperatures: J. A. DeMastry and E. L. Foster, Battelle Memorial Institute, Columbus, Ohio.

Effect of Various Gaseous Contaminants on the Strength and Formability of Columbium: H. E. McCoy and D. A. Douglas, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Aluminum Dipped Coatings on Columbium Alloys: R. G. Carlson, General Electric Co., Cincinnati, Ohio,

Carbon-Oxygen Relationship in Sintered Columbium: E. M. Grala and R. J. VanThyne, Armour Research Foundation, Chicago, Ill.

Pilot Quantities of Columbium-Base Alloys by Vacuum Arc Melting: S. J. Noesen, General Electric Co., Schenectady, N. Y.

THURSDAY, JUNE 9, 1960

Mechanical Properties 2:00-5:00 pm

Chairmen:
R. T. Begley, Westinghouse Electric Corp., Pittsburgh, Pa.
R. F. Hehemann, Case Institute of Technology, Cleveland, Ohio

Mechanical Properties of Cb-Al-V and Cb-Ti-W Alloys: W. F. Sheely and J. L. Wilson, Union Carbide Metals Co., Niagara Falls, N. Y.

Mechanical Properties of Columbium Alloys at Temperatures to 800°C: D. J. Maykuth and R. I. Jaffee, Battelle Memorial Institute, Columbus, Ohio.

Strain Aging Effects in Columbium Due to Hydrogen: B. A. Wilcox, Wright-Patterson Air Force Base, Ohio, and R. A. Huggins, Stanford University, Palo Alto, Calif.

Mechanical Properties of F-48 Columbium Alloy Sheet: T. K. Redden, General Electric Co., Evandale, Ohio.

Young's Modulus of Columbium Up to 800°C: D. P. Laverty, Thompson Ramo Wooldridge, Inc., Cleveland, Ohio, and E. B. Evans, Case Institute of Technology, Cleveland, Ohio.

Mechanism of Creep in Columbium and Columbium-1 pct Zirconium Alloy: D. P. Gregory and G. H. Rowe, Pratt and Whitney Aircraft Div., United Aircraft Corp., Middletown, Conn.

Effect of Grain Size, Strain Rate, and Temperature on the Yield Point of Columbium: E. S. Tankins, Naval Air Material Center, Aeronautical Materials Laboratory, Philadelphia, Pa.

Cocktail Party 6:00 pm
Banquet 7:00 pm

Speaker—W. J. Harris, Jr., Materials Advisory Board, Washington, D. C.

Subject:

A Critical Comparison of Columbium with Other Materials for Missile, Aircraft, and Nuclear Applications

FRIDAY, JUNE, 10, 1960

General Metallurgy 8:30-11:30 am

Chairmen:

R. I. Jaffee, Battelle Memorial Institute, Columbus, Ohio.

D. W. Levinson, Armour Research Foundation, Chicago, Ill.

Columbium-Nitrogen System: R. P. Elliott and S. Komjathy, Armour Research Foundation, Chicago, Ill.

Alloying Behavior and Compound Formation in Alloys of Columbium With Certain Transition Elements: A. E. Dwight, Argonne National Laboratory, Lemont, Ill.

Recovery and Recrystallization of Columbium-1 pct Zirconium Alloy: J. R. Stewart, W. Lieberman, and G. H. Rowe, Pratt and Whitney Aircraft Div., United Aircraft Corp., Middletown, Conn.

Recrystallization Behavior of Columbium-Vanadium Alloys: B. S. Shabel, F. W. Kunz, and D. L. Douglass, Knolls Atomic Power Laboratory, General Electric Co., Schenectady, N. Y.

Flow and Fracture Characteristics of Electron-Beam Melted Columbium: E. T. Wessel, L. L. France, and R. T. Begley, Westinghouse Electric Corp., Pittsburgh, Pa.

Some Physical and Mechanical Properties of Columbium Containing Oxygen: J. Enrietto, G. Sinclair, and C. Wert, University of Illinois, Champaign, Ill.

Some Aspects of the Reaction of Columbium With Hydrogen Gas: O. M. Katz and E. A. Gulbransen, Westinghouse Electric Corp., Pittsburgh, Pa.

Contribution to the Technology of Cb-Mo and Cb-W Alloys: H. Braun, K. Sedlatschek, and B. F. Kieffer, Metallwerk Plansee, Reutte, Austria.

Oxidation and Corrosion 2:00-5:00 pm

Chairmen:

J. L. Zambrow, Sylvania Nuclear Corp., Bayside, N. Y.
R. J. Wasilewski, E. I. duPont de Nemours Co., Wilmington, Del.

Oxidation of Cb-Al-V and Cb-Ti-W Alloys: S. T. Wlodek, Union Carbide Metals Co., Niagara Falls, N. Y.

FRIDAY, JUNE 10, 1960, Continued

High-Temperature Steam Corrosion of Columbium-Vanadium Alloys: H. A. Fisch and D. L. Douglass, Knolls Atomic Power Laboratory, General Electric Co., Schenectady, N.Y.

Ignition of Columbium and Selected Alloys: J. W. Clark, General Electric Co., Evendale, Ohio.

Oxidation of Columbium at Low-Oxygen Pressures: H. Inouye, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Formation of Oxide Films on Columbium: R. E. Pawel, J. V. Cathcart, and J. J. Campbell, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Hot-Water Corrosion Resistance of Columbium and Columbium Alloys: W. D. Klopp, R. I. Jaffee, W. E. Berry, and F. W. Fink, Battelle Memorial Institute, Columbus, Ohio.

Oxidation Rate of Columbium as a Function of Temperature and Pressure: J. E. Brady and J. N. Ong, Jr., Washington University, St. Louis, Mo.

Oxidation Resistance of Columbium Alloys in the Cb-Ti-Cr-Al System: S. Baranow and R. C. Lever, Aircraft Nuclear Propulsion Dept., General Electric Co., Cincinnati, Ohio.

General Information

Where: Sagamore Hotel, Bolton Landing, Lake George, New York

When: June 9 and 10, 1960

Advance Registration: Since space is limited, attendance will be limited to advance registrants. Please register before May 25 by writing A. E. Bibb, Jr., A-3-107, Knolls Atomic Power Laboratory, General Electric Co., Schenectady, N. Y.

Registration Fees:

AIME Members—$12.00
Non-Members —$20.00

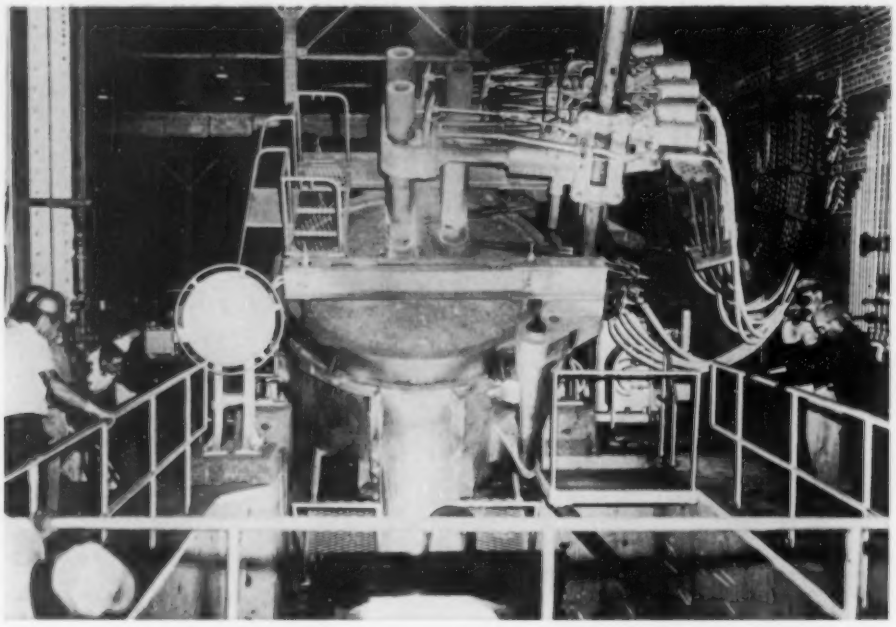
The above fees include the cost of a set of preprints of papers (available at the Conference), and a cloth-bound volume of the Conference Proceedings with discussion.

Hotel Reservations:

Single Room —$21.00 per day
Double Room (two occupants)—$18.00 per day

The above rates include all meals on June 9 and 10 and the cocktail hour on June 9. There will be a separate charge made for those guests arriving early who eat dinner on June 8, however. The hotel charges a gratuity fee of 15 per cent on each guest's bill.

Transportation: Although the resort village of Lake George itself is not accessible by air or rail, it can be reached from Albany by Greyhound bus, and by Eastern Airlines and Mohawk Airlines from nearby Glens Falls. It is the intention of the Sagamore Hotel to provide buses to meet those flights on which there are large numbers of Symposium attendees. It is therefore important that your flight number and day of arrival appear on the hotel reservation form. Taxi service is also available from Glens Falls to the Sagamore at $9.00 each for a load of five.



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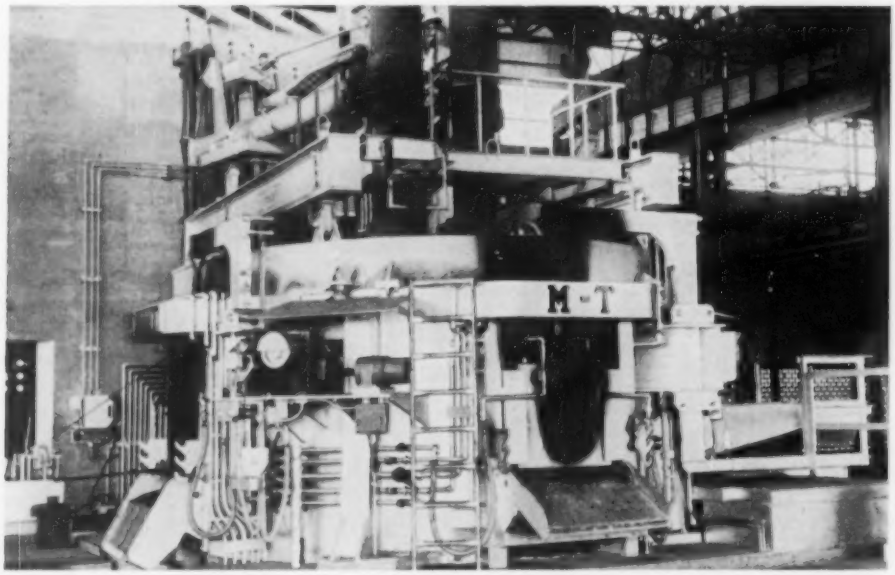

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ALUMINUM . . . AFRICA'S METAL

by F. Weston Starratt

A vast, untapped, low-cost, hydroelectric potential and a continually-mounting wealth of bauxite discoveries spell out aluminum, and the place is Africa. Most European and North-American aluminum producers are already on hand in several bauxite, alumina, and aluminum projects destined to put Africa on the map as the world's aluminum center.

Emerging from the undergrowth of west-coast African jungles are new export products: bauxite, alumina, and aluminum. And more can be expected, since few places in the world appear to offer such vast deposits of high-grade bauxite in close proximity to an enormous, and almost completely untapped, hydroelectric potential. Starting with French and Canadian activity in this area, almost the entire gamut of major European and North American aluminum firms have become actively interested in the continent's tremendous production possibilities.

Developments are moving at a rapid pace: bauxite mining has been undertaken in Guinea since 1952; aluminum output in Cameroon began in 1957; and this month alumina shipments from the FRIA plant in Guinea commenced. For the future, various large-scale aluminum projects are being investigated in Guinea, Cameroon, Ghana, the Congo Republic, the Belgian Congo, and Angola.

Initial exploration for bauxite deposits in this region was largely undertaken by Aluminium Limited in what was then known as French West Africa. In 1942, during the German occupation of France, the two French producers of aluminum—Pechiney and Ugine—sent forth a mission to the tropics of Africa to search for bauxite and to survey the hydroelectric potentialities of the region. For some years these two firms had been keenly aware that increasing French aluminum requirements could not be met by an expanded capacity based solely on increasingly expensive French power resulting from the exploitation of less-economic hydroelectric sites. Furthermore, lower-cost power would greatly enhance the position of French aluminum in the world market. The eyes of Pechiney and Ugine were, thus, turned toward Africa where bauxite deposits and hydroelectric possibilities appeared favorable.

First in Guinea

In Guinea prospecting teams found a large deposit of bauxite at Fria in close proximity to the Konkouré river, which appeared capable of producing the necessary power required for a large-scale aluminum reduction works. Later studies, carried out by a subsidiary of Pechiney and Ugine, resulted in the formulation of plans for mining bauxite and erecting an alumina plant at Fria. But further investigation showed that, although the hydroelectric potential of the Konkouré could be tapped at Souapiti in a long-range project, the immensity of the earth-moving job was too great to provide the desired power within the available time.

Thus, Pechiney and Ugine began a search for an alternate source of hydroelectric power and a location for an aluminum reduction works. Such a site should not be too distant from the west African coast in order to permit low-cost transport of alumina from Fria and access to ocean transport for aluminum. The site was found along the Sanaga river in Cameroon; it was at the town of Edea.

Africa's first aluminum

At Edea, a two-stage construction project on a relatively minor scale was capable of ensuring an output of more than 1000 million kw-hr per year (at 125,000 kw during the rainy season) from the Sanaga river. For the construction of the aluminum plant, Pechiney and Ugine in December 1954 combined to form the firm known as ALUCAM. The result was erection of a 45,000-metric-ton-per-year plant near the power station of Edea. While not directly on the ocean, the alumina is transported the 55 miles from the port of Douala by rail at a relatively low cost.

In 1957 production commenced . . . the first aluminum to be produced in Africa! Before that year ended, some 7500 metric tons were produced, and full-capacity production of 45,000 tons was attained in 1959. The plant itself comprises three electrolysis buildings, containing a total of 208 soderberg cells, each of 100,000 amp; they are in series and made up of four units of 52 cells.

Capacity of the Edea plant will probably be expanded in the future, and the plant may also be able to draw upon alumina produced from Cameroon bauxite. Recent discoveries have shown the existence of large-scale deposits of bauxite in an area some 700 miles from the coast. Other more accessible deposits may be discovered.

Alumina from Fria

While originally a French project, the actual development of mining capabilities and construction of processing installations has been done by an international consortium, the FRIA Compagnie Internationale pour la Production de l'Alumine, better known as FRIA. This association of French, American, British, Swiss, and German capital, while engaged in construction of the largest alumina plant in Europe and Africa—a capacity of 480,000 metric tons per year—has also built a 96-mile railroad link between Fria and the Conakry harbor . . . developed that harbor for handling the quantities of raw materials and alumina required . . . and built a town near Fria. Estimated cost for the entire project is $155 million.

Deposits in the Fria area have proven reserves of 200 million tons of bauxite. But, "considerable variations in the grade of ore are found and the overall quality is not high." So reported G. A. Daniels and S. F. Derbyshire of The British Aluminium Co. in a paper, *Bauxite Deposits of the World*, presented at a recent symposium in Australia (see JOURNAL OF METALS, April 1960, pp. 338-339). The authors went on to say that, "because these . . . deposits lie close to potential hydroelectric power projects on the Konkouré river and can be converted into alumina *in situ*, thus avoiding transport costs, they become an economic source of raw material for alumina production." The average analysis is 41 pct alumina, 24 pct iron oxides, and 1.5 pct silica, the remainder being water of hydration.

FRIA alumina is produced by the Bayer process in a plant whose design features are based on results of pilot operations carried out in Pechiney's Gardanne plant in southern France (see JOURNAL OF METALS , January 1958, pp. 38-43). With quantities of FRIA alumina scheduled to be shipped to European ports, returning ships are bringing raw materials from there to FRIA, thus creating a low-cost, two-way flow of materials through Conakry. Fuel oil is being brought in for power generation and

Fig. 1—The first aluminum plant in Africa at Edea, Cameroon.

heating. Limestone is feeding FRIA's lime kilns, and soda ash is used with the resulting lime for the production of caustic soda for the Bayer process.

FRIA started up operations early this year, with the first shipment of alumina from Conakry made this month. However, it may be 1965 before full-scale operation is achieved.

Alumina produced by FRIA can be purchased from the company by participating firms in proportion to the respective percentage of ownership—Olin Mathieson 48.5 pct, Pechiney and Ugine 26.5 pct, AIAG (Swiss) 10 pct, British Aluminium 10 pct, and Vereinigte Aluminiumwerke (German) 5 pct. Thus, FRIA alumina may find its way into markets in Europe and the US, as well as serving as a raw material for the Edea plant and future west African aluminum reduction works.

In Guinea itself there may be a market for FRIA alumina, if an aluminum reduction works is built adjacent to Fria and the proposed Souapiti hydroelectric project on the Konkouré river. AFRAL, a study group of European aluminum producers, has investigated the construction of a 150,000-ton aluminum plant, but it is dependent upon the development of the Souapiti hydroelectric project. Capital requirements are high, and participation by the World Bank or a similar group appears to be a necessity. Such participation would now appear to be dependent upon a settling of political dust in fast-moving Guinea.

Alumina from Boke?

Start-up of activity at Fria is not Guinea's baptism into the aluminum picture. Since 1952, Aluminium Limited has been mining high-grade bauxite on the Isles de Los near Conakry. This is a high-grade ore which can be shipped to producing centers without further processing. Current output is at the rate of 500,000 tons annually.

In addition, Aluminium Limited holds mining rights to a large, high-grade deposit near Boké, in return for which the firm has agreed to the erection of a 220,000-ton-per-year alumina plant to be completed by mid-1964. Expenditures for the project would be on the same order as for FRIA, since a railroad must be built to transport alumina and bauxite to Kakande, where a harbor is to be cut into the coast. Aluminium Limited has, thus, called upon US producers to participate in the $150 to $200 million project. Reynolds, Aluminum Co. of America, Kaiser, and Olin Mathieson have responded and declared their desire to participate in the development of a Boké bauxite/alumina project.

Prospects for Ghana

Ghana also has its share of high-grade lateritic bauxite deposits, which are being looked at with an ever-more-careful eye by major aluminum-producing firms. Aluminium Limited has been interested in prospects in Ghana since 1947, when it acquired a bauxite position there, and it has participated in subsequent study groups.

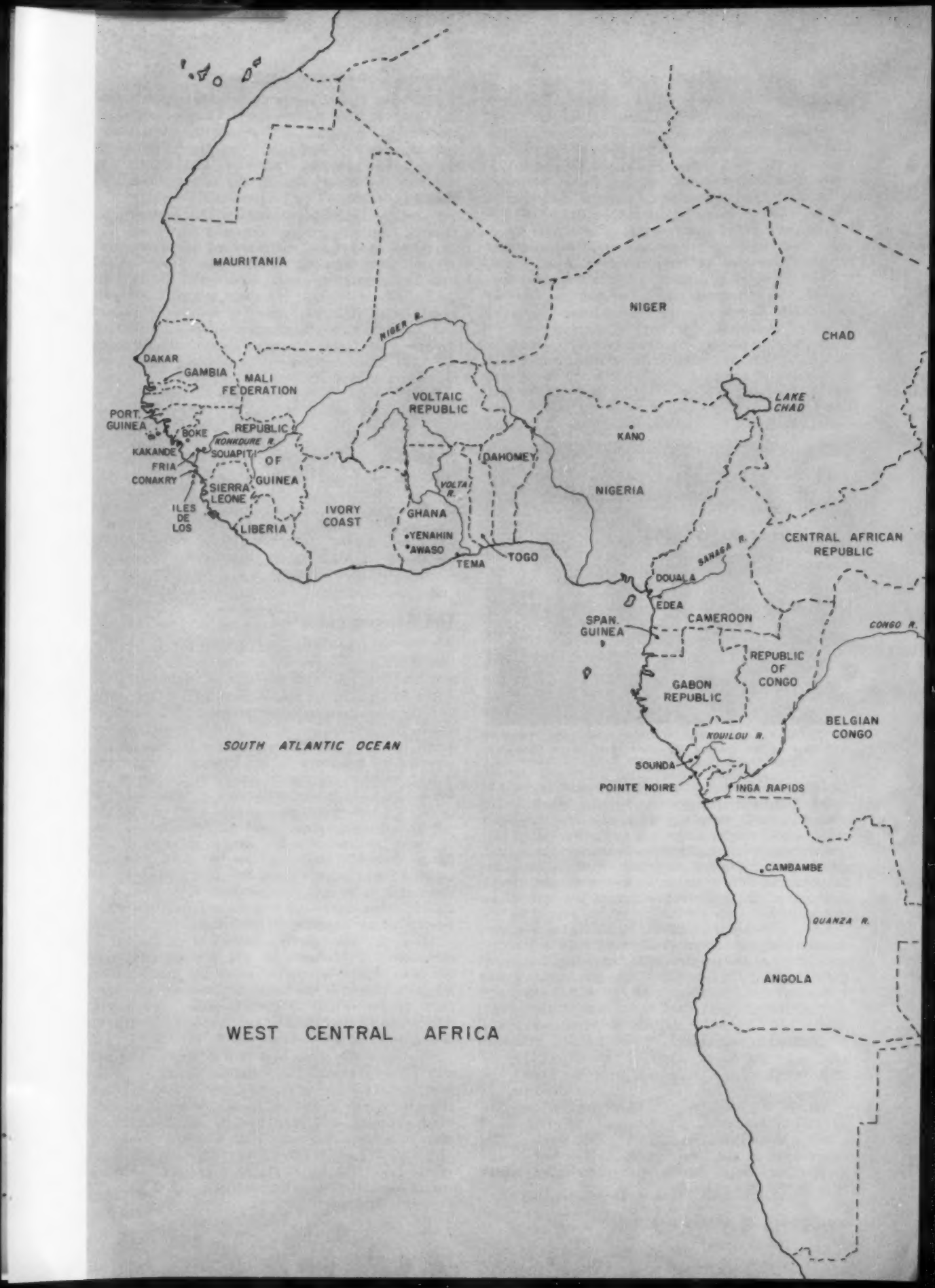
But the only deposits being worked at the present time is that at Awaso, where mining on a limited scale has been undertaken since 1942 by the British Aluminium Co., in which Reynolds Metals Co. now holds a substantial interest.

In Ghana, the magic words are the Volta river project, a hydroelectric scheme adjacent to bauxite deposits near Yenahin. At the request of the government of Ghana, Kaiser Engineers is engaged in engineering design of the hydro developments including a rock-fill dam and power plant. This phase of work encompassing preparation of contract documents is to be completed this fall.

The project, as presently conceived, calls for the construction of a $168-million power project designed to provide a potential of 512,000 kw. The second stage is the construction of a 120,000-ton aluminum plant and other industrial units.

Kaiser is actively engaged in consultations with other aluminum producers with a view toward the formation of an international consortium to be known as the Volta Aluminium Co. Upon its formation, the consortium is expected to negotiate with the government for the construction of an aluminum plant at Tema, the new port in Ghana. Participation by this consortium, the government of Ghana, and an international lending authority may be required to meet the financial requirements of the hydroelectric project. Power costs in the range of 3 mils can be anticipated.

(Continued on page 388)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Power from Middle Congo?

As in the other new countries of west Africa, the sparkle of independence and industrialization, based on hydroelectric power and the establishment of industries such as aluminum, has captured the imagination. In the Congo Republic the key is Kouilou, major river of that country. At Sounda on that river one of the largest hydroelectric projects of equatorial Africa is being planned, with a potential of 800,000 kw, thus some 6500 million kw-hr annually. But it is more than a power project, for it includes a vast industrial complex for the production of aluminum, ferroalloys, calcium carbide, magnesium, and phosphorus. Site of these plants is the main port city of the Middle Congo—Pointe Noire—some 100 miles distant from Sounda.

The Kouilou project appears to be moving ahead in its initial phase, with present construction comprising completion of a road from Pointe Noire to Sounda and the building of a construction camp at the dam site. In the meantime, negotiations are underway to secure capital for the hydroelectric project. Financial

Fig. 2—FRIA's alumina plant in Fria, Guinea. In the immediate foreground are the agitated disilication tanks; in the right background the calcination kilns are visible.

participation by the French government seems assured, and assistance by the World Bank is being sought. Already formed is an association of private firms which might make use of power from the project. This grouping includes Pechiney, Ugine, and other French firms, together with Aluminium Limited and Olin Mathieson; they may participate in the financing and construction of the hydroelectric project.

As for the aluminum plant, an international group of aluminum producers was formed in 1958 to carry out a study of the project. Included are the following firms: Pechiney, Ugine, Vereinigte Aluminiumwerke (German), Montecatini (Italy), AIAG (Swiss), British Aluminium, Olin Mathieson, Kaiser, and Aluminium Limited. Plans thus far advanced include a 250,000-ton aluminum reduction works at dockside in Pointe Noire. Alumina can be brought by ship from Conakry in Guinea, since the Congo Republic apparently lacks suitable bauxite deposits.

Active negotiations are underway among the various participants, and assuming the granting of a World Bank loan, this project has the seeds of fulfillment, since the hydroelectric site is one of the most favorable in Africa with promise of power costs in the area of 2 mils.

Belgian Congo and Angola

Of all the hydroelectric projects proposed, probably that at Inga on the lower Congo river most staggers the imagination. Perhaps the largest untapped sources of low-cost hydroelectric power in the world, the potential is estimated at 25 million kw, although the initial step of the scheme has been lowered to a 700,000 kw project.

These hydroelectric possibilities, plus the financial backing of the Belgian government augur well for the power project and the proposed development of an aluminum industry in the Congo. Furthermore, bauxite deposits have been reported in the Belgian Congo. Already formed is a study group . . . known as ALUMINGA . . . composed of Belgian industrial and banking interests, together with a number of European and North American aluminum producers. A 90,000-ton reduction works is being considered as the initial capacity.

Further south, along the west African coast in the Portuguese colony of Angola, Pechiney is also at work on preliminary studies for another aluminum plant. This one is in conjunction with Aluminio Portuguese (Angola) and concerns the construction of a 50,000-ton-per-year reduction works. The plant would start producing at the rate of 25,000 tons. A hydroelectric station at Cambambe on the middle Cuanza river would produce an estimated 1420 million kw-hr annually (approx 150,000 kw), of which the aluminum plant would absorb some 920 million when in full operation.

The African potential

These, then, are the major projects for the utilization of Africa's almost unlimited deposits of bauxite and her enormous hydroelectric potential.

The FRIA alumina operation is already a reality, as is the aluminum reduction works at Edea in Cameroon. But realization of the various other projects along the west African coast greatly depends on securing the necessary outside financial aid, which is in turn based on the capital required . . . the cost of the power to be made available . . . transportation costs . . . and operating costs . . . as well as the stability of the countries involved. From most points of view, the vast low-cost power schemes of the Congo Republic and the Belgian Congo appear closest to realization. On the other hand, there is also something to be said for the Volta river project in Ghana, since apparently it has something the other two do not have—adjacent bauxite deposits.

All in all, the power potential of the region is enormous; it claims to be the greatest untapped source of hydroelectric power in the world today. Amazing indeed is the dichotomy between the present meager output of electric power in western Africa and a potential sufficient "to light each tree of the tropics like a Christmas tree."

What does this mean to Africa in the years of her political awakening? The economic, social, and political questions are fascinating, but we must leave these for others to discuss. As for the world's aluminum supplies, it is predicted by one top-ranking aluminum executive that, "Within 30 years time half of the world's entire aluminum production will be in Africa". To this we might add, political stability would seem to be the only condition.

TERMINAL B. S. PROGRAM IN METALLURGY
An Industrial Viewpoint

Presenting industry's point of view, the author calls for a relatively large number of specialized options, with two general types of undergraduate course: one emphasizing the broad fundamentals with later graduate specialization; the other covering the fundamentals of metallurgical engineering practices.

by W. R. Hibbard, Jr.

To obtain a quick picture of the rapid changes occurring in B.S. metallurgical education in the US, we need only glance through the articles in last October's special issue of JOURNAL OF METALS. A more detailed look will result from a comparison of the curricula in university catalogues 20 years ago and now. In 1940, programs were aimed primarily at the producer industries, which employed most of the B. S. graduates who did not continue on to graduate school. These budding engineers in the producer companies were concerned primarily with production, development, or use (customer service). Metallurgy in the consumer industry was, for the most part, performed by the producer, since the consumer would usually refer his new or *sticky* problems to the supplier for solution from available, or nearly available, materials. In addition, the production and development of new materials usually was stimulated by producer talents and by domestic economic competition. New materials generally were not consumer dictated, and competition among the metal producers was usually met by the process of evolution.

In 1940, educational needs of the profession could be met by a single program of study containing options. The student continuing on to graduate school learned most of his advanced science there. The number of such graduate students was meager, however, because of limited financial support from industry, which supplied specialized training to the graduate by on-the-job courses and training assignments.

Changed conditions

Advances of the nuclear and space age and the international technological competition have become so dependent upon materials that:

1) The consumer can no longer depend upon the producer to solve his problems with existing metals and alloys (i.e., most of the recent new alloy developments have originated with consumers, e.g., F-48 columbium alloys, Renée 41, Four Square Silicon Iron, Bi-Sb-Te, etc.);
2) The competition is no longer only between metals but reaches across the whole materials field;
3) Metallurgical development can no longer be left to domestic economic competition, but must be closely allied to consumer needs, which are frequently essential to international competition;
4) There is an increasing tendency for all good students to continue on to graduate school because of the increased availability of financial support; and
5) Today's urgency obsoletes specialization by industrial experience and on-the-job training.

As a result of these changes, B. S. metallurgists are not only employed by metal producers and basic fabricators, but are also needed in even greater numbers by electrical, automotive, aircraft, metalworking, oil, and chemical industries, as well as the government, research and development institutes and, of course, universities themselves. A single undergraduate program with an option or two does not satisfy all these needs. The science and engineering learned in undergraduate college cannot avoid obsolescence within the career of the graduate. He not only must be prepared to cope with the existing practice of metallurgical engineering, but must be prepared within his professional lifetime to apply new knowledge and understanding now not available.

Specialized options

It seems to me that to meet these diverse needs of industry there must be available a relatively large number of specialized options—probably more than one single department can competently develop without a large faculty of specialists. Thus, it would appear desirable that a given department decide to satisfy only certain of these industrial requirements —depending upon the type of student it attracts, the knowledge and skills of its faculty, to some extent the geographical location of neighboring industry, and possibly the industrial needs it has been successfully fulfilling in the past.

Thus, a department that has always sent large numbers of students to graduate schools might design its program specifically for this purpose. A department located in the steel-producing areas might concentrate its options in the science and technology of steelmaking. The department with close ties to the consumer industry might tailor its options to meet these needs.

Moreover, specialized options should be broad enough to minimize technological obsolescence. This type of specialized education, of course, has been carried out to some extent for years, but I emphasize that now it should be recognized as essential to meet the contemporary industrial needs.

Two roads?

Some say that every student should be trained in

W. R. HIBBARD, JR. is Manager of the Metallurgy and Ceramics dept., General Electric Research Laboratory, Schenectady, N. Y.
This paper was presented at the 1960 AIME Annual Meeting.

the broad fundamentals, as if he was continuing to graduate school. In my judgment, this practice would be unwise, because the student who is concluding his training at the undergraduate level would not have time to cover the fundamentals of existing metallurgical engineering practices, and he would not be prepared to enter industry without additional education and training. Only a few companies can provide this additional education through their own programs at the pace now required.

A contrary belief is that only the good student should be trained in fundamentals for graduate school, and that a student who cannot meet the entrance barriers should be shunted into more applied courses. In my opinion, this also would be very unfortunate, because the metallurgical engineering problems faced in industry today require just as capable a graduate as does research and education.

Proposed curricula

Now let us look at details. First of all, there is a need for basic science—chemistry, physics, and mathematics—in such detail as to obtain a feeling for the framework within which nature operates.

Then there is a need for engineering science—statistics, dynamics, electricity, thermodynamics, and some analysis and synthesis. Again, these subjects should be pursued, not to obtain a practicing knowledge of these fields, but primarily to understand their relation to metallurgical engineering.

Certain fundamental courses in metallurgical engineering also are required in order that the student may learn about the interactions of its various branches, i.e., aspects of mineral resources, mining, refining, production, alloying properties, structure, processing and fabrication, application and use, and economics. These subjects should be covered in principle and in practice, using the common denominators of underlying science and technology. The program at this stage might be similar in scope to those of 20 years ago, but detailed coverage would be different, reflecting progress since then.

Finally, option studies would cover in depth the fundamentals of that branch of metallurgical engineering which interests and stimulates the student and in which the department provides leadership, for example, steelmaking, fabrication and forming, processing, application, and use, for research.

Engineering today is an opportunistic formulation of existing metallurgical practice (both lore and technology) and science (both existing or acquired) used to produce an idea to meet the needs of society. These ideas may be new and creative, and certainly they must be economically reasonable. The practicing engineer must be skilled in various stages of this process and must have a working knowledge of its ingredients. To obtain these skills and this knowledge, he must know fundamentals on a broad base and know how they have been applied in his area of specialization.

I believe that many departments of metallurgical engineering have recognized these needs, and programs of the type I have described are in existence today. We need more of them!

... B. S. ... An Educator's Viewpoint

by John E. Dorn

Arguments may be presented for a dual course of undergraduate study: metallurgical engineering and metallurgical science. The author presents evidence in favor of a unified course of study with specialization at the graduate level only.

Coincident with the ever-mounting emphasis on research, a question has arisen as to whether universities should organize two programs of study in metallurgy: one, perhaps called *metallurgical engineering*, that is especially designed for those terminal B. S. degree students who plan to enter the production and management fields of the industry; the other, perhaps called *metallurgical science*, for those who wish to become research metallurgists. Although this question is well-defined, no single answer seems yet to have been formulated. This is possibly a healthy condition which permits each university to seek the area of its most effective contribution to the total educational effort. But on the other hand, it behooves both the teaching profession and industry to probe deeply into this, a subject so important to the efficiency of the educational system and to the future vitality of the economy.

Facts and arguments in favor of the two program approach can be marshaled. But evidence of perhaps equal weight can be presented in support of a unified engineering-science program in metallurgy.

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Separate programs?

Before presenting arguments in favor of a unified program, I should like to review and then discredit some of the arguments offered in support of separate programs. The reasons for suggesting two programs arise from the belief that the research metallurgist and the production metallurgist are uniquely different people who play uniquely different roles. These differences are thought to be inherent accouterments to achievement in each field of activity. It is a prevalent belief that the members of each group, in order to achieve greater and more comprehensive results, should be given the intellectual background for their specialized roles and the opportunity of exercising their separate talents as early as possible. Thus, it goes, they will be trained to think and act more effectively as engineers or scientists. If such differences do exist, they then constitute an argument which justifies the two programs of education. But if such differences are only apparent, having been falsely introduced into our way of thinking by overly zealous efforts toward distinct classification by social science professionals or by personnel departments, then we not only do not need two programs but, indeed, such programs may actually prove to be harmful.

Differing attributes?

The attributes conducive to success in research and high-level development are numerous. Let us ascertain whether these differ in any basic way from the attributes of a successful engineer or manager:

1) **Intelligence:** I believe the record clearly reveals that the metallurgical scientist must possess an effective brain. Knowledge of this fact has led some opinionated metallurgical scientists to assume a false superiority over management and production engineers. Brilliant minds, wherever they are found, are at a premium. But the research metallurgist has no monopoly on them. The problems confronting management and production engineers are no less weighty than those of the research scientist. We cannot and dare not divert all of our brains into research and development. We must provide an educational system that insures an adequate supply of brains to the management and production efforts of the economy. It might even be argued that, in view of the growing economic war, this should be our major current effort.

2) **Knowledge:** It is perhaps trite to state that a successful metallurgical scientist should have a broad and deep knowledge of his subject. A successful manager or production engineer often needs a broader basis of knowledge, although in certain limited areas the same depth is not essential. It is frequently thought that the kind of knowledge needed by a manager or production engineer differs in content from that needed by a scientist. This assertion, however, is somewhat false because the scientist needs the same background in economics, social science, English, and psychology as the manager and production engineer. It, therefore, appears that the kind of knowledge both groups need is the same, and differences occur only with respect to intensity in the various areas.

3) **Imagination:** The objectives of creativity—the duty of the scientist—have emphasized his need for a vivid and rational imagination. But in management and production leadership demands just as much imagination to cope with the ever-changing complex problems encountered.

4) **Personality:** In viewing the various problems of personality, very little can be documented that distinguishes the successful research scientist from the successful manager or production engineer.

Once the decision is reached that a unified program of instruction will be adopted—thus satisfying the needs of both the terminal B. S. degree student and the student who plans to take post-graduate studies—a certain philosophy must necessarily be fostered in formulating the professional stem of subjects to be included in required courses of instruction. For example, it is not desirable from several viewponts to delve deeply into current specialized industrial techniques. Such emphasis would result in so diluting the over-all instruction as to make it ineffective. And although such emphasis might give the recent graduate a more rapid assumption of industrial productivity, his outlook might be confined to the limited areas of his previous instruction, and his imagination so sterilized that he would not be attuned to visualize new and better techniques. A unified program assumes that an educated employee will prove, in the long run, to be more effective than a trained employee. On this basis the unified program should emphasize broad basic principles, and the breadth of the professional stem of the program can easily encompass, at the undergraduate level, the principles of extractive metallurgy, physical metallurgy, and ceramics without danger of superficiality.

Although the actual details of course instruction to meet the measurements for broad, basic education in the principles of metallurgy will vary extensively from university to university, certain general requirements can, nevertheless, be established in terms of the needs of the profession. Metallurgy is the science and engineering utilization of the chemical and physical properties of metals; therefore, the student of metallurgy should acquire a background in the following subjects:

1) Mathematics—at least up to the definite integral and the solution of partial differential equations;
2) Physics—including modern physics and solid state physics;
3) Chemistry—including a strong course in physical chemistry; and
4) Engineering—mechanics, strength of materials, theory of elasticity, theory of plasticity, and electronics.

Most of this background might best be undertaken in the first two years of college instruction and the remainder in the third year. This would allow introduction of part of the specialized professional subjects during the junior year and the rest (at a very high level) in the senior year.

The great strength of the unified program so far outlined is contained in its depth and breadth. For this reason, rapid progress at a high level can be expected in the special professional courses to be undertaken in the junior and senior years. The usual technique of adding professional courses that satisfy the interest or whims of a professor cannot, and should not, be adopted in composing the unified program. Rather, it is more effective to review the disciplines essential to the professional metallurgist. One such listing is as follows:

a) Phase diagrams,
b) X-ray and metallographic structures,
c) Thermodynamics,
d) Kinetics of reactions,
e) Physical metallurgy and ceramics, and
f) Extractive metallurgy and chemical ceramics.

All of these subjects can be developed in such a way as to satisfy the needs of the extractive and physical metallurgist, and also the ceramist, by appropriate portrayal of application of principles to each of these areas. In this way, the emphasis on basic principles can be maintained throughout the program, and the breadth and depth required in a non-specialized undergraduate program for the future manager, production engineer, and the research specialist can be realized in a single, well-formulated program.

Graduate specialization

The time for specialization with appropriate emphasis on metallurgical research or metallurgical engineering and management is at the graduate level. Before this time the student seldom has either the background or the fixity of purpose to make an effective decision on this important issue. Here two parallel programs might prove to be profitable: one for the research metallurgist, and another for the production metallurgist and potential manager. At present some universities do offer reasonably well-organized programs for research metallurgists. But most universities in the US have neglected the much-needed post-graduate programs for the high-level production engineer.

ULTRASONICS FOR METALLURGICAL TESTING AND MEASUREMENT

by J. B. Morgan

An ever-more important metallurgical tool is ultrasonics. Its applications are many and include those of detection of discontinuities and measurement of thickness. These are described in some detail.

Ultrasonics is a term that has been chosen to describe the portion of the sonic spectrum above the limit of human hearing. Since the upper limit of audibility for the young adult is generally accepted to be 15,000 to 16,000 cycles per sec, ultrasonics includes all frequencies above this value. Generally, but not always, power applications employ the lower frequencies—20,000 to 40,000 cycles per sec—while ultrasonic testing is normally done in the megacycle range—0.5 to 25 million cycles per sec.

Applications for ultrasonics are growing so rapidly that today there are few fields in which it has not found a use. In metallurgy, the applications are numerous. Not all of them are now commercially feasible, but they are presently of interest or useful from a research standpoint, and in time many of those not now commercially practical will probably be made so.

Applied ultrasonics in the field of metallurgy can be divided into two general classifications: testing or measurement and power applications. Ultrasonics, in the last decade or so, has found wide acceptance as a non-destructive testing tool for the detection of discontinuities. It is also used for thickness measurements and the determination of elastic constants. Power applications include cleaning, degreasing, descaling, degassing, grain refinement, welding, and soldering.

Ultrasonics waves or mechanical vibrations are generally produced for testing purposes by use of a piezoelectric material, such as quartz, lithium sulfate, or certain titanates. In pulse-type equipment, such as the Reflectoscope, Immerscope, and Sonoray, an electrical pulse of short duration is applied to the piezoelectric material, commonly called the transducer or search unit. By means of its piezoelectric characteristics, the transducer converts the electrical energy into mechanical energy. The high-frequency mechanical vibrations or ultrasonic waves are transmitted from the transducer to the article to be inspected through a layer of oil, water, or some other suitable couplant. This is necessary since high-frequency sound will not travel through air.

The type of wave present in the article is dependent on the manner in which the quartz blank is cut from the crystal or the angle at which the ultrasonic beam strikes the entry surface. An x-cut blank produces longitudinal waves, where particle motion is in the direction of the wave propagation. A y-cut blank produces shear waves, where particle motion is perpendicular to the direction of wave propagation. In ultrasonic testing, x-cut blanks are generally used. Shear waves or surface waves (waves which travel along the surface of the article with only slight penetration below the surface) are commonly produced by adjustment of the angle at which the ultrasonic beam strikes the surface of the article. Refraction follows Snell's Law.

Contact method of testing

In the ultrasonic inspection of metal products for discontinuities such as cracks, voids, or inclusions, two principal methods are employed: contact and immersion. The older of the two, and the one still widely used, is the contact method. With this

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method, the search unit is directly contacted to the surface of the article to be inspected through a thin film of couplant. The ultrasonic waves travel through the article until they reach the far surface —commonly called the back surface—where they are reflected back to the search unit. If, during their travel through the article, they encounter a discontinuity, a portion or all of the ultrasonic beam may be reflected at this point, depending on the magnitude of the discontinuity. The search unit converts these reflections or echoes into electrical pulses which are, in turn, amplified and displayed on the cathode-ray tube screen of the instrument.

Fig. 1 shows a typical screen presentation. Indication 1 represents the sound beam leaving the crystal. In the contact method, this indication—called the initial pulse—is coincident with the entry surface. The horizontal spread of this indication is generally larger than later indications. The search unit is struck with a burst of electrical energy, and it *rings* for a relatively long time. The degree to which the crystal is damped determines the time duration for which it rings. If one considers the start of the trace (left-hand side of the screen) as 0 time, all events that occur are displayed on the screen in chronological order from left to right. Obviously, if it is desired to display events occurring shortly after the sound enters the article, the initial pulse must be kept short. This may be done by damping the crystal, lowering the voltage applied to the crystal, or using a high test frequency. In practice, a higher test frequency is usually applied.

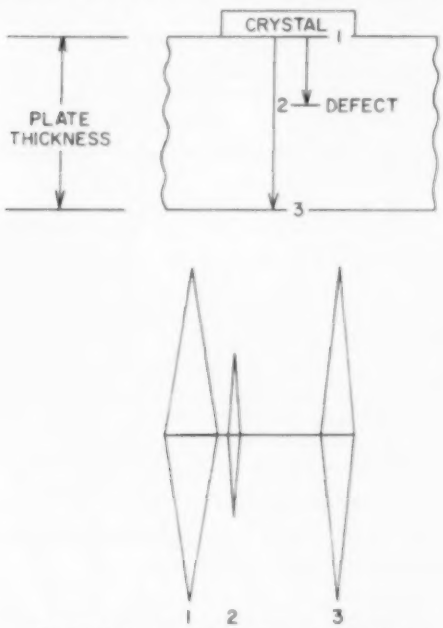


Fig. 1—Contact method of ultrasonic inspection.

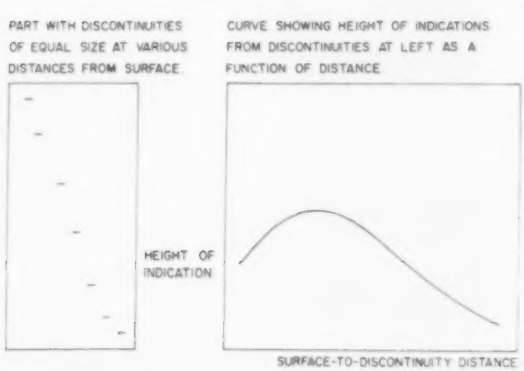

PART WITH DISCONTINUITIES OF EQUAL SIZE AT VARIOUS DISTANCES FROM SURFACE
CURVE SHOWING HEIGHT OF INDICATIONS FROM DISCONTINUITIES AT LEFT AS A FUNCTION OF DISTANCE
HEIGHT OF INDICATION
SURFACE-TO-DISCONTINUITY DISTANCE

Fig. 2—Effect of distance from surface on the height of indication for different discontinuities.

Indication 2 of Fig. 1 represents sound reflected from a discontinuity encountered by the ultrasonic beam during its travel. Indication 3 represents the far or back surface of the article. This indication is commonly called the *back reflection*. Although not shown in the figure, the screen pattern consists of many more indications. All of the sound is not received by the search unit on the sound's first complete trip. It keeps bouncing back and forth resulting in multiple back reflections and discontinuity indications.

Using the time concept previously mentioned, the depth of the discontinuity below the entry surface can be determined, since the time base of commercial instruments is essentially linear. Knowing that the thickness of the article is represented by the horizontal displacement between the start of the initial pulse and back reflection, a unit of length along the trace line can be equated to a unit thickness of the article being inspected; for example, 1 in. of horizontal displacement on the screen might equal 6 in. of steel. Electronic markers, which can be displayed on the screen, are also provided.

The height of indication from the discontinuity gives some information as to the size of the discontinuity, although there are many variables which must be considered. At first it might be suspected that a certain loss in ultrasonic energy would be encountered per unit distance traveled by the ultrasonic beam, and this might be constant for material of a particular type. For example, it might be suspected that the farther away a discontinuity of a certain size is from the entry surface, the less the amount of ultrasonic energy reaching it would be. Consequently, a smaller amount of energy would be reflected, resulting in a smaller height of indication on the cathode ray tube screen. However, in practice it is found that this is not the case. If a plot is made of the height of indication from a certain size discontinuity (as a function of the distance of the discontinuity from the transducer), a curve such as shown in Fig. 2 is generally obtained. Initially, the height of indication increases as distance increases. At a distance which appears to be determined by the size of the transducer and the test frequency, the height of indication reaches a maximum. This portion of the curve is called the *close field* or *Fresnel zone*. The extent of the zone is approximately equal to $\frac{D^2}{4\lambda}$, where D = diam of the transducer and λ = ultrasonic wavelength in the material being inspected. Beyond the close field, i.e., in the far field, the height of indication decreases exponentially in true attenuation as the distance increases. In the close field, if the search unit is moved horizontally over the discontinuity, it is found that the response from the discontinuity goes through a series of maxima, i.e., a plot of height of indication as a function of the horizontal displacement of the search unit with respect to a discontinuity may show five or more

peaks. The number of peaks observed varies from point to point in the close field. Fig. 3 shows typical response curves in the close field.

The height of indication received from a discontinuity depends on the transmissibility of the material. For example, the instrument controls might be set to obtain a 2 in. indication from a $\frac{1}{8}$ in. diam flat-bottomed hole in a Type-304 stainless steel block. Using the same instrument settings, the indication obtained from a hole of the same size in another Type-304 block might not be observable, or may be very low in amplitude. Such factors as grain size can have an appreciable effect on the amount of ultrasonic energy lost during transmission through a material. Fig. 4 shows the difference in transmissibility of two blocks of the same chemical composition but having different grain sizes.

The height of indication received from a discontinuity also is influenced by the nature of the reflecting surface offered by the discontinuity. In standardizing ultrasonic test equipment so that a comparable test can be conducted from day to day and the same level of sensitivity for testing can be used by customer and supplier at various locations, reference blocks are commonly used. An ultrasonic reference block generally consists of a metal block containing a hole of specified size and depth. It has become standard practice to use flat-bottomed holes for this purpose, since the flat-bottom of the hole offers the optimum reflecting surface, and it is reproducible. Differences in height of indication obtained from a flat-bottomed hole and a conical-shaped hole can easily be as large as 50 pct. Fig. 5 shows the manner in which the ultrasonic beam is reflected from the two types of surface. Obviously, the nature of the reflecting surface offered by natural discontinuities in material can vary widely. In a product that has received little or no working, a void may be spherical in shape. With working, this may flatten, offering a better reflecting surface. If there is included material associated with a void, the reflecting surface may conform to the shape of the inclusion.

Because of the various factors that affect the height of indication obtained from a discontinuity, it is difficult to determine with precision the size of a discontinuity. The ultrasonic test is, thus, more qualitative than quantitative in this respect.

Angle beam units

The contact method as described thus far assumes the use of a straight beam search unit, i.e., the ultrasonic beam travels essentially perpendicular to the entry surface. Other search units in use are called angle beam search units. In these units, the crystal is generally held at a fixed angle to the entry surface by means of a plastic wedge.

In the commonly used shear wave units (where particle motion is perpendicular to wave propagation), the plastic wedge angle is such that the ultrasonic beam travels through the article being inspected at 45° to the entry surface, as shown in Fig. 6. It bounces back and forth between the entry and back surfaces until it encounters a discontinuity or reaches the far end. From the name of the unit, it should be observed that shear waves rather than longitudinal waves (generally associated with straight beam search units) are predominant in the article being inspected.

If the wedge angle is increased beyond that used in the shear wave unit, it is possible to produce waves that travel essentially at the surface of the article being inspected and have a depth of penetration equal to one or two wavelengths. This is called a surface wave search unit.

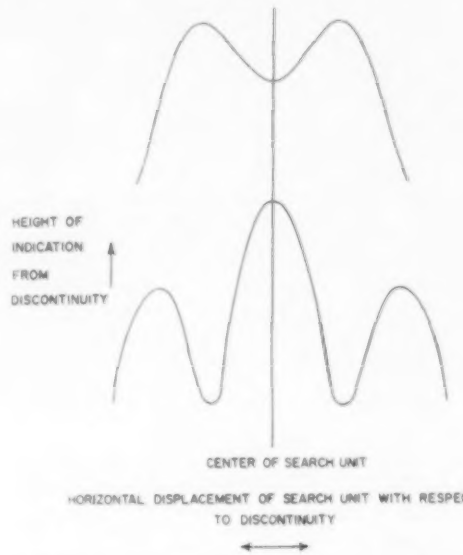


Fig. 3—Response curves with search unit moved over discontinuity in the close field.

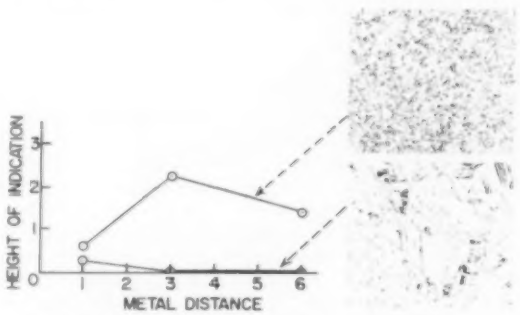


Fig. 4—Effect of grain size on ultrasonic test results.

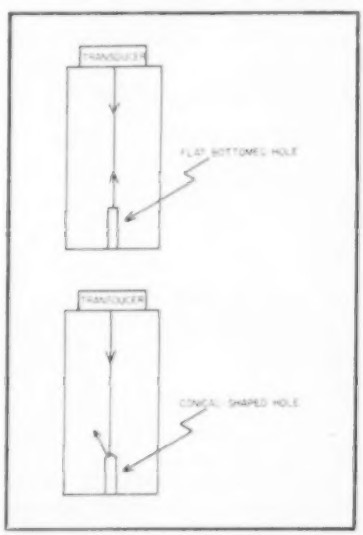


Fig. 5—Ultrasonic beam reflection from two types of surface.

Of the various types of contact search units, the straight beam type is most widely used. It is used for the detection of internal discontinuities such as cracks, voids, and inclusions in a variety of products such as billets, bars, plates, and forgings. Angle beam search units are used for the detection of internal as well as surface discontinuities; however, their use is usually, but no necessarily, limited to thin sections such as plate and tubing. Surface wave search units are used for the detection of surface discontinuities lying just below the surface. They obviously find use in the inspection of material such as sheet, strip, and tubing.

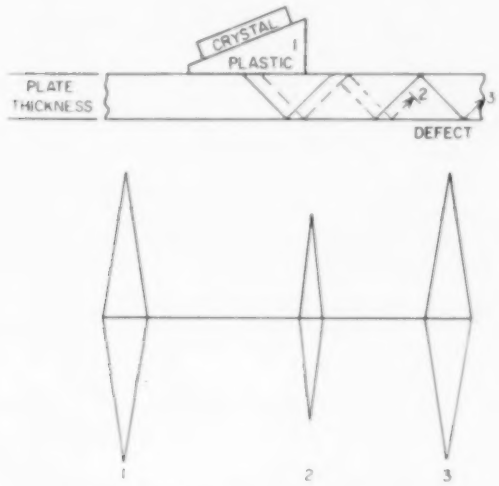
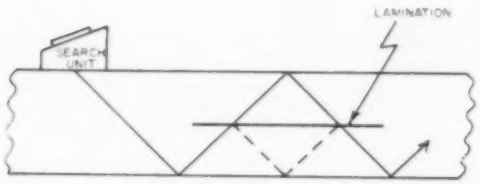


Fig. 6—Angle-beam type of ultrasonic inspection.



SOLID LINE SHOWS TRAVEL OF ULTRASONIC BEAM IN METAL SECTION WHEN LAMINATION IS NOT PRESENT. DOTTED LINE SHOWS TRAVEL OF BEAM WHEN LAMINATION IS PRESENT. DISTANCE TRAVELED IS THE SAME IN BOTH CASES.

Fig. 7—Effect of lamination with angle-beam search unit.

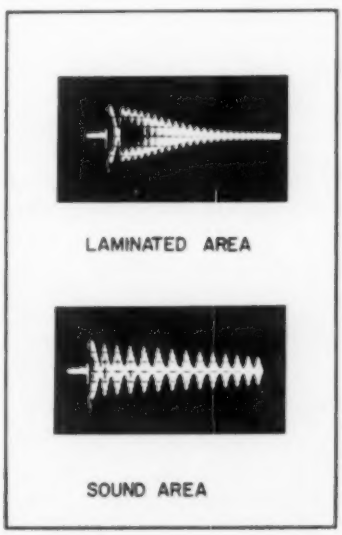


Fig. 8—Difference in back reflection pattern caused by lamination in a 0.2 in. thick section.

In the inspection of thin sections, the straight beam unit may not be satisfactory because of the horizontal spread of the initial pulse. In some instances, the initial pulse and back reflection may merge with each other so that there is no clear separation between them to observe discontinuity indications. In such instances, angle beam units may prove helpful.

In the detection of laminations, shear wave units may be insensitive. If there are rough projections associated with the lamination, energy may be reflected back to the search unit, indicating the presence of a discontinuity. But where the lamination surface is smooth and flat, it can act as a back surface; Fig. 7 shows this condition. Even where initial pulse and back reflection merge when using a straight beam unit, laminations can often be detected by a complete change in screen pattern, i.e., successive back reflections fall closer together. Fig. 8 shows the difference in back reflection patterns caused when passing over a lamination in a 0.2 in. thick section.

Immersion method

As previously mentioned, in addition to the contact method of ultrasonic inspection of metal products, there is another principal method called the immersion method. This method differs from the contact method in that the search unit is not directly contacted to the article being inspected, but is separated from it by an appreciable layer of couplant. This usually consists of 1 in. or more of water.

Fig. 9 shows a typical screen pattern and the search unit-article placement. The first indication at the left-hand side of the screen is, as in the contact method, the initial pulse. It is indicative of when the sound first leaves the crystal. The next indication to the right of the initial pulse occurs as the result of energy reflected from the entry surface of the article. The space between the initial pulse and entry or front surface indication represents the travel of the ultrasonic beam through the water. If the search unit was raised farther above the article, the front surface indication would move to the right on the screen. Indication 3 represents the discontinuity encountered by the ultrasonic beam during its travel through the article. Indication 4 represents the far or back surface of the article.

As with the contact method, the sound is not all received by the crystal on its first complete trip. Instead, it bounces back and forth, resulting in multiple or high-order reflections from the front and back surfaces and discontinuities. In the immersion method, however, this feature becomes important. If the water layer between the search unit and the article is not great enough, the second-order front surface indication will appear between the first front and back surface indications. This is un-

desirable, since it may mask a discontinuity. Fig. 10 shows the screen patterns obtained when sufficient and insufficient water layers are used. To prevent this, at least 1 in. of water for every 4 in. of metal is used. This ratio of 1 to 4 is based on the ultrasonic velocities in the two media.

An advantage of the immersion method is that test frequencies higher than those practical with the contact method can be used, since with the immersion method the search unit does not contact the article. The transducer becomes thinner as frequency increases, so that above 5 mc they are very fragile. High test frequencies may be advantageous in detecting discontinuities close to the surface and in detecting small discontinuities. It should be pointed out, however, that in normal practice 2¼ and 5 mc test frequencies are generally used. At these frequencies, it is possible to detect very small discontinuities, and good penetration is obtained unless grain size is large. Penetration decreases with increasing frequency since wavelength becomes smaller and scattering becomes more pronounced.

The immersion method permits angular adjustment of the search unit with respect to the article being inspected. The ultrasonic beam can be directed to reflect a maximum amount of energy back from discontinuities lying at an angle to the entry surface. In the immersion method, the search unit is usually mounted on a movable carriage so that it can be readily moved the length and width of the immersion tank. This permits rapid scanning of the article.

Thickness measurement

Pulse-type ultrasonic test equipment, in addition to detecting discontinuities, finds some use in measuring the thickness of material. This is done by noting the deviation between the horizontal position of a higher-order back reflection of the material to be measured and the same-order back reflection of a material of known thickness. It is necessary, of course, that the two materials be of the same general type so that velocity is not a variable. Ultrasonic thickness measurement is particularly useful where only one surface of the article is accessible.

Although pulse-type equipment is used for thickness measurement, resonance-type ultrasonic equipment is more widely used for this purpose. This equipment differs from the pulse-type in that the sound is sent continuously rather than in short bursts. A variable frequency oscillator is used to excite the transducer, which again may be a quartz crystal or some other piezoelectric material. The transducer is contacted to the surface of the article to be measured through a thin film of suitable couplant, such as oil or water. Vibrational amplitude increases appreciably whenever the ultrasonic wave frequency equals the natural resonant frequency of the article. This latter frequency depends on the thickness of the article.

There are a number of ultrasonic resonance-type instruments on the market, and the indicating devices differ. Most employ a cathode-ray tube. The horizontal base line indicates the frequency range. Vertical indications represent the thickness resonance. Indications are obtained at the fundamental as well as harmonic (higher-order) frequencies,

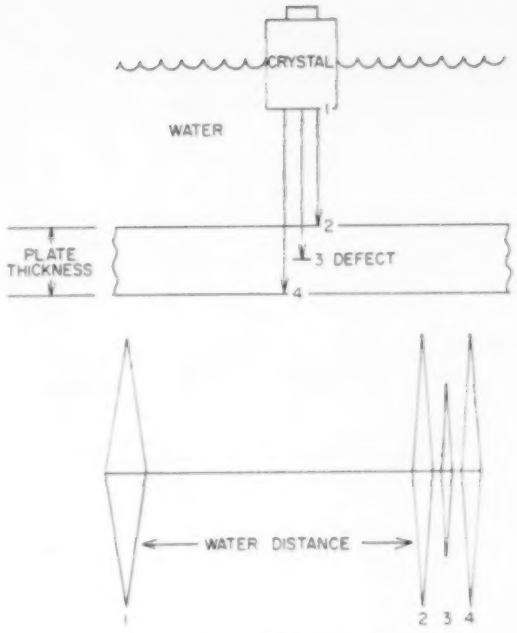


Fig. 9—Immersion method of ultrasonic inspection.

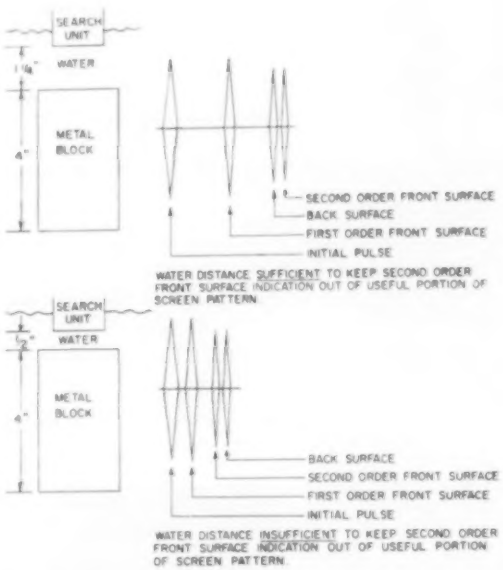

SEARCH UNIT
WATER
METAL BLOCK
SECOND ORDER FRONT SURFACE
BACK SURFACE
FIRST ORDER FRONT SURFACE
INITIAL PULSE
WATER DISTANCE SUFFICIENT TO KEEP SECOND ORDER FRONT SURFACE INDICATION OUT OF USEFUL PORTION OF SCREEN PATTERN
SEARCH UNIT
WATER
METAL BLOCK
BACK SURFACE
SECOND ORDER FRONT SURFACE
FIRST ORDER FRONT SURFACE
INITIAL PULSE
WATER DISTANCE INSUFFICIENT TO KEEP SECOND ORDER FRONT SURFACE INDICATION OUT OF USEFUL PORTION OF SCREEN PATTERN

Fig. 10—Effect of water distance between search unit and inspected article, as shown on the screen pattern.

and scales are normally available that will read thickness directly from either type. Other types of indicating devices employed are earphones and output meters. With this equipment, the frequency at which resonance occurs is read from a calibrated scale, and thickness is determined from the relationship of $f = V/2t$ where f = resonant frequency, V = ultrasonic velocity in the material whose thickness is being measured and t = thickness of the material. For convenience, conversion scales or tables are available for common materials.

Resonance-type equipment is also used for de-

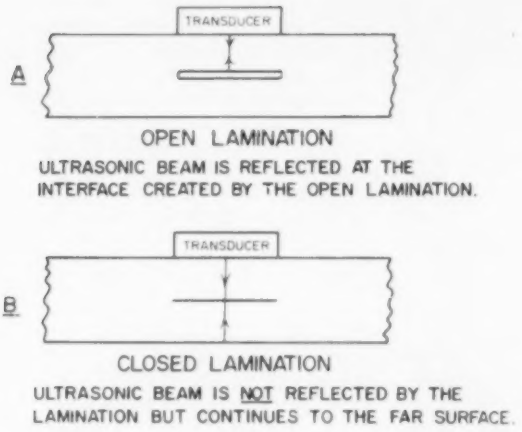

TRANSDUCER
A
OPEN LAMINATION
ULTRASONIC BEAM IS REFLECTED AT THE INTERFACE CREATED BY THE OPEN LAMINATION.
TRANSDUCER
B
CLOSED LAMINATION
ULTRASONIC BEAM IS NOT REFLECTED BY THE LAMINATION BUT CONTINUES TO THE FAR SURFACE.

Fig. 11—Ultrasonic beam traveling through open and closed laminations.

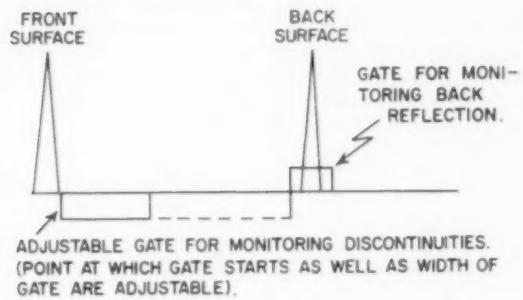

FRONT SURFACE
BACK SURFACE
GATE FOR MONITORING BACK REFLECTION.
ADJUSTABLE GATE FOR MONITORING DISCONTINUITIES. (POINT AT WHICH GATE STARTS AS WELL AS WIDTH OF GATE ARE ADJUSTABLE).

Fig. 12—Gate arrangement for monitoring ultrasonic tests.

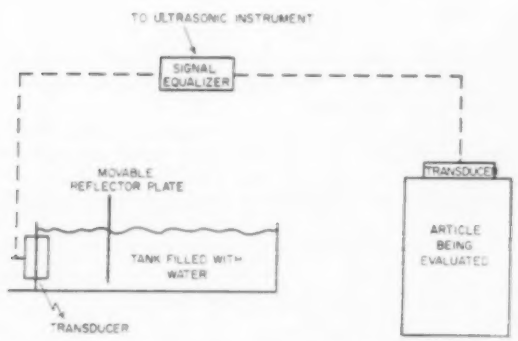


Fig. 13—Set-up for ultrasonic determination of elastic moduli.

tecting laminar-type discontinuities. The size of the discontinuity must approach or be larger than the size of the transducer in order to be detected. Otherwise, enough energy gets past the discontinuity to yield the normal screen pattern. Experience has also shown that if the interfaces of the laminated area are in intimate contact, the lamination may not be detected. Apparently, in this situation sufficient energy passes through the interface without reflection to the normal screen pattern. Where the lamination is open, no difficulty is encountered in its detection. Fig. 11 is a sketch showing the travel of the ultrasonic beam in both instances.

Automatic equipment

In describing the ultrasonic test equipment no mention has been made of the automatic equipment available. This type of equipment is sometimes useful on a production inspection basis, but, in many applications, can prove more a hindrance than an aid. Included in this automatic equipment are means for driving the search unit the length of the tank and indexing laterally when employing the immersion method. Gating circuits are available that will signal when a discontinuity exceeding some predetermined level is encountered. The position of the gates can be set to monitor any desired thickness layer or even the entire thickness of the article.

Fig. 12 shows a possible gating arrangement for monitoring ultrasonic tests. With resonance-type ultrasonic equipment, the gate may be set to signal whenever the thickness varies above or below some set limit. With pulse-type equipment, a gate can be set so that a signal is given whenever the back reflection decreases below a certain predetermined value. This can be used to assure proper transducer contact and transmission through the article.

Determination of elastic constants

Ultrasonics can be used to determine elastic constants, such as Young's Modulus, Shear Modulus, and Poisson's Ratio. One method of doing this is to employ a velocity comparator in conjunction with pulse-type ultrasonic equipment. A typical set-up is shown in Fig. 13.

The velocity comparator consists of a small tank which is filled with water. A movable reflector plate is provided whose position can be accurately determined with respect to an immersion-type search-unit affixed at one end of the tank. This immersion search-unit and a contact search-unit coupled to the article being evaluated are simultaneously connected to the ultrasonic instrument. Provisions are made for equalizing the heights of the signals obtained from both search units. The back reflection from the article and the signal from the reflector plate are superimposed by adjusting the water path between the search-unit and plate in the tank. The first back reflection and several higher-order back reflections from the article are used and an equivalent water path measured in each case. Arriving at an average water equivalent for the metal thickness of the article (the ultrasonic velocity in water is accurately known), it is possible to determine the velocity in the article. Separate sets of data are obtained using x-cut and y-cut crystals for the generation of longitudinal and shear waves so that both wave velocities can be determined. Knowing these two velocities and the density of the material, the moduli and Poisson's Ratio can be determined by the use of appropriate formulae.

Conclusions

Several methods for the detection of internal and surface discontinuities, the measurement of thickness, and the determination of elastic constants have been described. These are only a few of the more important applications of ultrasonics in the field of metallurgy. New uses are continually being found and developed. Ultrasonics is, thus, becoming an increasingly more versatile and useful metallurgical tool.

THE DHHU PROCESS FOR VACUUM TREATING MOLTEN STEEL

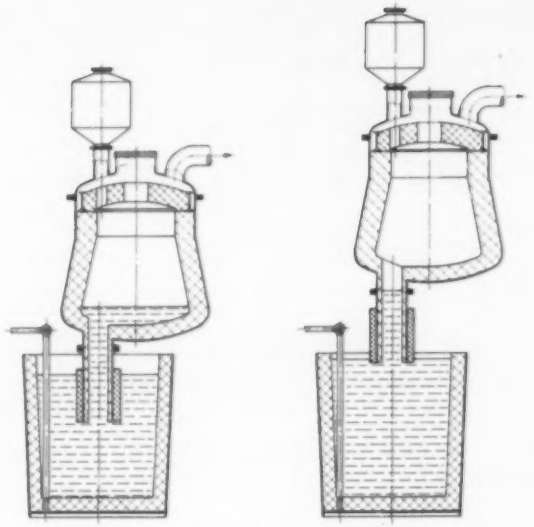


Fig. 1—The Dortmund-Hoerder Heuttenunion vacuum treatment apparatus.

by Fritz Harders, Helmut Knuppel, and Karl Brotzmann

A brief description of the Dortmund-Hoerder Huettenunion process for the vacuum treatment of molten steel, together with recent operating data from Dortmund, Germany.

Almost 100 years ago the possibility of improving molten steel by treatment under reduced pressure was first considered. Patent literature published as early as 1880 to 1890 includes several proposals for production-scale steel degassing. After these early disclosures, some 50 years passed before it became possible to treat the first melts in small vacuum units. Only recently—during the last five years—have production-scale steel-degassing processes been put into operation. One of these processes was developed by Dortmund-Hoerder Huettenunion in Germany and is now in successful operation at several plants.

The heat to be degassed by the DHHU process is tapped into a normal teeming ladle and transported to the treatment unit. As shown in Fig. 1, the molten metal is forced into the treatment vessel in successive portions by a cyclic change in the immersion depth of the suction nozzle. After degassing, each portion of steel returns to the teeming ladle, thereby mixing with the balance of the steel, which has a higher gas content. This is fundamentally different from other processes in which either the entire melt is exposed to the vacuum, or the molten steel is poured into a vacuum.

The cyclic nature of the process establishes a definite relationship between the total throughput of molten steel and the required degree of gas removal. The total throughput is given by the quantity

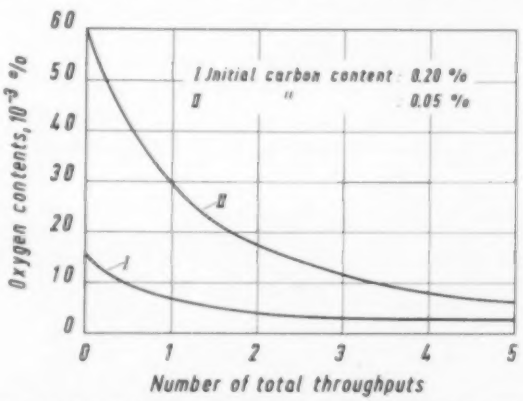


Fig. 2—Relation between throughput and oxygen content for steels with 0.20 and 0.05 pct initial carbon content. Recirculation factor: 4; pressure reduction from 50 to 5 mm Hg.

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of steel drawn into the vessel during each cycle and the number of cycles per treatment. This is expressed by the *recirculation factor*, which is a measure of the average number of times each particle of the melt is exposed to the vacuum.

For the case shown in Fig. 2, an initial oxygen content of 0.015 pct has been selected—corresponding to a steel containing about 0.2 pct C. From this figure it can be seen that a recirculation factor of one reduces the initial oxygen content by slightly more than 50 pct and that after a three-fold recirculation no further significant reduction is effected.

In view of such factors as normal temperature loss in the ladle, stopper life, and crane scheduling, the entire treatment should not exceed 15 min. Of this time, 3 min are needed for the addition of alloying and deoxidizing agents at the end of the treatment, leaving 12 min for gas removal.

From this it follows that one of the most important requirements for the effective operation of the DHHU process is the achievement of high flow rates through the nozzle of the treatment vessel. For example, for a three-fold recirculation of steel from a 200-ton ladle, the rate of steel flow through the nozzle is 100 tons per min. This may be calculated by considering that half the treatment time is needed to fill and the other half to empty the vessel, and all the steel in the ladle must circulate three times within 12 min. These high flow rates may be achieved with ease, provided adequate nozzle diameters are selected.

Advantages of DHHU

Multiple circulation has several useful effects. The rapid recirculation of the steel produces thorough mixing, consequently, deoxidizing and alloying elements, even though added late in the treatment cycle, are uniformly distributed throughout the heat. The degree of gas removal obtained at any time during treatment is indicated by the variation of the pressure in the treatment vessel.

These characteristics lead to the following important advantages of the process:

1) The oxygen content of the heat is known at all times during treatment, and its final level can be controlled exactly;
2) Semi-killed steels with a low carbon content can be produced;
3) The analysis can be corrected and/or maintained within very close tolerances by making additions in the treatment vessel;
4) Savings are effected in alloying and deoxidizing additions; and
5) Trace elements such as aluminum, boron, titanium, zirconium, and columbium can be used with precision and economy irrespective of their oxygen affinity.

An exclusive feature of the DHHU process is the resistance heating system for the treatment vessel. Fig. 3 shows temperature loss during treatment of a 70-ton ladle of steel plotted against heat input to the treatment vessel. The discontinuity in the curve at about 200 kw corresponds to the power required to heat the treatment vessel to the temperature of molten steel before treatment. It can be seen from the figure that, if the vessel is only partially preheated, for example, up to one-half the temperature of molten steel, considerable additional temperature loss occurs, mainly due to the large heat capacity of the degassing vessel. On the other hand, the figure

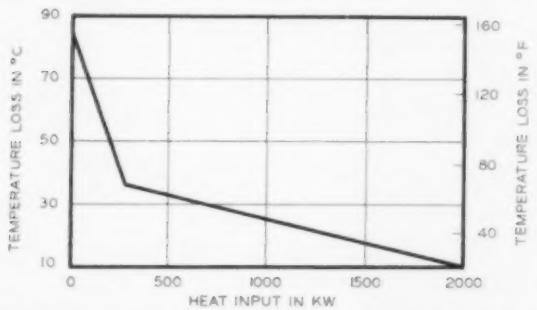

Fig. 3—Temperature loss during treatment of 70-ton ladle heat vs heat input to treatment vessel in kw.

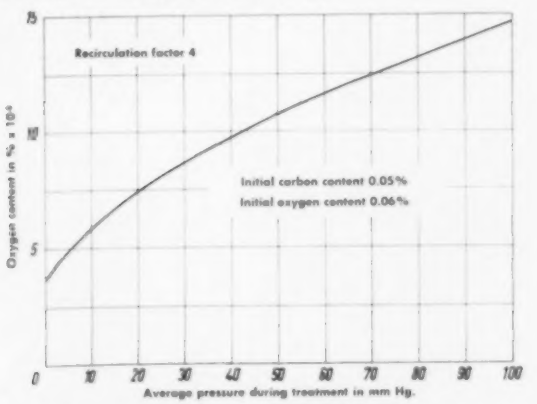

Fig. 4—Oxygen content and average treatment pressure after fourfold recirculation.

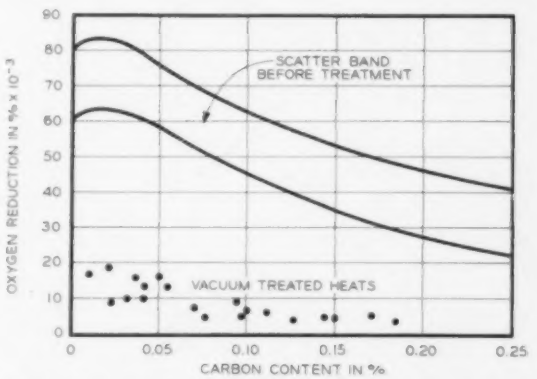

Fig. 5—Carbon and oxygen content of molten steel before and after vacuum treatment.

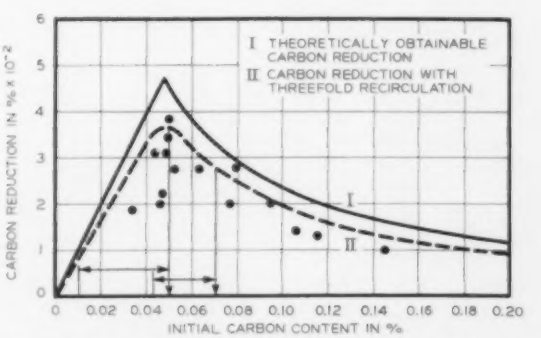

Fig. 6—Carbon reduction as a function of initial carbon content.

also shows that heating power above 200 kw leads to insignificant reduction in temperature losses. These higher power inputs should be applied only when molten steel is in the vessel, i.e., during treatment, because of the danger of refractory damage. Heating systems of considerably higher power—1000 kw and above—are under development, but they are not yet in satisfactory operation. For the time being, it is practical to apply only sufficient power to raise the treatment vessel to the temperature of molten steel or slightly above. However, a reserve of power is normally included to make rapid heat-up possible.

Treatment of mild carbon grades

In all conventional melting processes operating under atmospheric pressure, reduction of carbon content to very low levels means the acceptance of a correspondingly high oxygen content. This oxygen increase in the bath increases FeO in the slag, thus augmenting the severity of the attack on furnace refractories. This effect, combined with the slowness of the oxidizing reaction at low carbon levels, makes reduction of the last few points of carbon in mild steel heats both difficult and expensive. However, a low carbon content is particularly desirable in many tonnage grades, such as deep drawing strip and electrical sheet. Pressure reduction provides a good means of reducing oxygen and carbon simultaneously in mild steel heats.

Fig. 4 shows the relationship between the final oxygen content of the steel and the treatment pressure. Most of the gas should be released at a relatively high pressure and the balance at a lower pressure because of the danger of excessive turbulence, leading to splashing and clogging of the openings provided for alloy additions and the vacuum connection. The gas content of a mild steel heat during treatment is indicated in Fig. 2, where the pressure was lowered from 50 mm Hg down to 5 mm Hg.

The vacuum treatment unit developed by DHHU was built about five years ago for use on relatively high carbon heats. The initial objectives—elimination of hydrogen flaking and major reduction of oxide inclusions—were completely achieved. Using a 70 to 80-ton ladle, a total treatment time of 18 min provided a recirculation factor of about 2.5 before the addition of alloying elements. Since the vacuum system was also designed for the treatment of forging grades, conditions for the treatment of low carbon steel were not particularly favorable. However, considerable reduction of carbon and oxygen contents was obtained, as shown in Fig. 5. The upper scatter range represents average carbon and oxygen contents according to both DHHU results and published figures on the production of open hearth and LD steels. The lower scatter range shows carbon and oxygen contents for vacuum-treated steel. As can be seen, the relocation of the range by vacuum treatment is quite significant.

The oxygen reduction is effected by the carbon-monoxide reaction during treatment. Fig. 6 shows the carbon reduction associated with the oxygen reduction during vacuum treatment. Curve I shows the carbon reduction which would occur if all the oxygen in the melt could react with the carbon. Curve II is based on the fact that there is always a residual oxygen content, as shown in Fig. 2, therefore, the actual carbon reduction is slightly less than shown in Curve I. Isolated points in the diagram indicate some actual results from vacuum-treated heats. It can be seen that, if a heat of 0.04 pct C is required, steel should be brought to the treatment vessel at 0.07 pct C. In order to produce a steel of approximately 0.015 pct C, the initial content must be about 0.05 pct.

In some recent heats, carbon was reduced from 0.05 pct to 0.011 pct by vacuum treatment, without the use of oxidizing agents. After this decarburizing reaction, required additions of deoxidation and denitration agents and, if necessary, alloying elements are made in the treatment vessel. It can be seen that this process is of particular interest to the producers of electrical steels. The silicon is added to the heat during several cycles in the treatment vessel and is completely mixed. No reladling practice is required. In spite of their low carbon contents, these heats

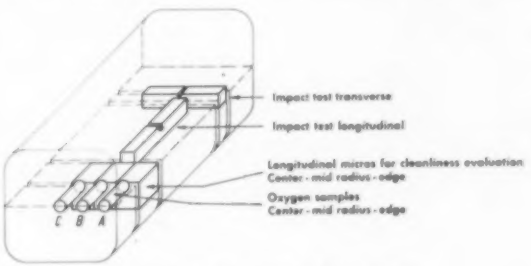
Impact test transverse
Impact test longitudinal
Longitudinal micros for cleanliness evaluation
Center - mid radius - edge
Oxygen samples
Center - mid radius - edge
C B A

Fig. 7—Sample location in billet section.

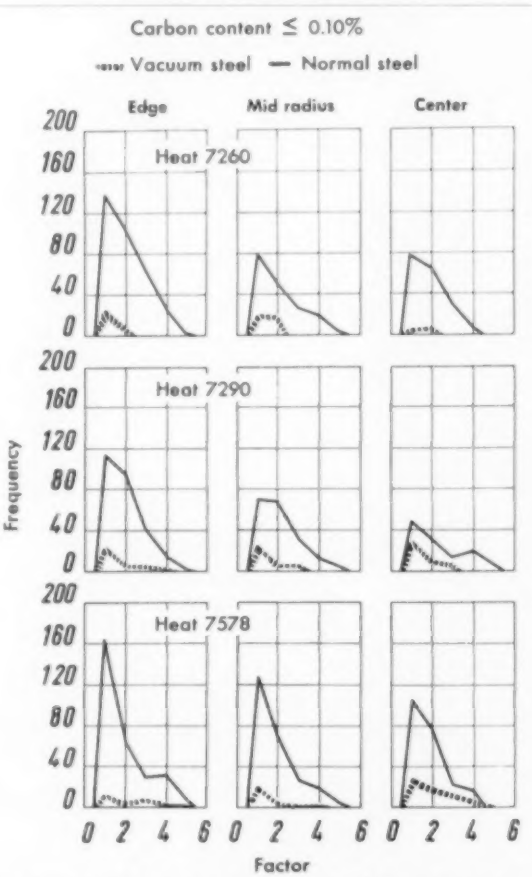

Fig. 8—Number of stringer-type oxides for 0.55 sq in. for low-carbon steel. X100.

are virtually free from oxide inclusions because the additions are made after the oxygen is removed.

Properties of vacuum-treated steel

Up to this point, the carbon and oxygen values apply to molten steel. But, the following is a report on the effects of vacuum treatment in steel after rolling.

Across the ingot section: In all cases, the heat was split and the steel from the first treated ladle compared with that from the second untreated ladle. Fig. 7 shows the location of the samples for chemical and microscopic examination, as taken from billet sections corresponding to the center of the ingot. For this report, a total of 24 unalloyed heats with carbon contents ranging from 0.07 pct to 0.55 pct were investigated. The furnaces were 150-ton tilting open hearths.

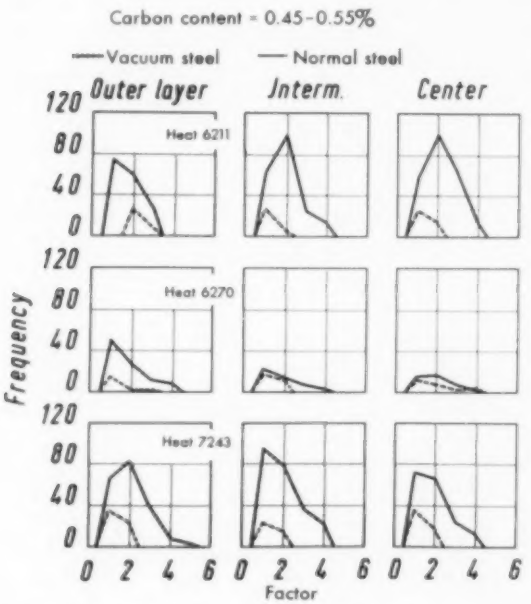

Fig. 9—Number of stringer-type oxides for 0.55 sq in. for medium carbon steel. X100.

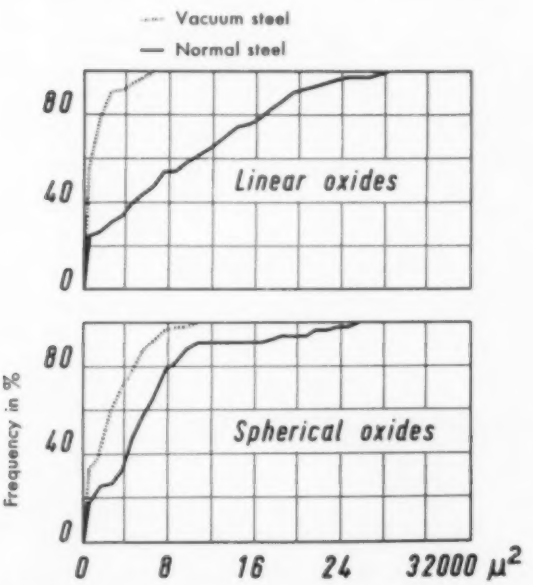

Fig. 10—Microscopic cleanliness rating for vacuum and untreated steel. Inclusion area for 0.55 sq in. microarea. X100.

The lower diagram of Fig. 11 shows the oxygen distribution in the ingot section for these 24 heats. It is clear in all cases that the vacuum-treated steel is superior to the untreated steel in three respects:

1) Oxygen contents are lower;
2) Distribution of oxygen over the ingot is more uniform; and
3) The differences in oxygen content for heats with the same carbon content are smaller in the case of vacuum-treated steel than for the untreated steel.

It should be noted that, after vacuum treatment, high oxygen contents are not present in the edge zone of rolled material from heats with less than 0.15 pct C. This large reduction in oxygen content, determined by chemical analyses, was confirmed by microscopic examination. Transverse micros taken parallel to the direction of rolling were used for these examinations. The micro samples were located one sawblade width away from the oxygen samples. Evaluation of the degree of cleanliness was based on the Diergarten table.

A basis of comparison was obtained by plotting the frequency of occurrence of each inclusion against its size. In Fig. 8, the distribution of stringer-type oxides in heats with carbon contents below 0.10 pct is shown. For example, in heat No. 7260, 140 factor I inclusions were found in the edge of the billet of untreated steel compared with only 24 of these inclusions in the equivalent inspection area of the corresponding vacuum billet. This inspection area was 0.55 sq in. All the diagrams in Fig. 8 indicate that the frequency of stringer-type inclusions is very much lower in vacuum-treated steel than in the same steel untreated. Further, coarse oxide inclusions with factors of III to VI are relatively frequent in untreated steel, whereas vacuum-treated steel shows almost none.

These results were verified in heats with higher carbon contents. Fig. 9 shows frequency and distribution of stringer-type oxide inclusions in micros from heats with 0.45 pct to 0.55 pct C. The difference of total inclusion contents between vacuum-treated and untreated steel is also quite apparent for these heats.

The degree of cleanliness is determined not only by stringer-type oxides, but also by spherical oxides. Fig. 10 illustrates the number of stringer and spherical-type oxide inclusions in micros from all of the heats examined. The cross-sectional area of the inclusions in the 0.55 sq in. area of each micro sample was calculated for this diagram, using the evaluated frequency and inclusion size factor. The upper diagram of Fig. 10 shows the frequency curve for the total area of stringer-type oxide inclusions. The maximum inclusion area for vacuum-treated steel was 0.95×10^{-4} sq in. in an area of 0.55 sq in. and for untreated steel the maximum inclusion area was 4.35×10^{-4} sq. in.

Over half of the micro samples from vacuum-treated steel contained no stringer-type oxides. For untreated steel this was true of only one-quarter of the samples. The spherical oxides follow the same pattern as the stringer-type oxides: 34 pct of the

micros from vacuum-treated steel were free from spherical oxides; the figure was only 18 pct from untreated steel. Vacuum-treated steel had a maximum inclusion area of 1.55 x 10^{-4} sq in. and untreated steel, 3.9 x 10^{-4} sq in.

A general, though not pronounced, reduction of the A and B-type (sulfide) inclusions was noted when comparing vacuum-treated material with the untreated material. This reduction takes the form of an increase in the total number of smaller sulfide inclusions combined with a decrease in the number of large inclusions. This indicates that vacuum treatment tends to break up and redistribute the sulfides.

In order to summarize the microscopic cleanliness discussion, the oxygen distribution across the ingot section is shown as the lower diagram in Fig 11. The upper diagram of Fig. 11 shows the total inclusion areas for stringer and spherical-type oxides across the ingot section. The curves are drawn through points representing average values.

Comparing the microscopic with the chemical evaluation, it can be seen that both investigations lead to the same conclusions:

1) Vacuum-treated steel is considerably cleaner than equivalent untreated material;
2) Significantly smaller differences in cleanliness and oxide distribution occur across the ingot section for treated compared with untreated steels;
3) Vacuum-treated steel shows consistently good cleanliness ratings compared with inconsistent and much worse ratings for untreated steel.

Over the ingot length: In addition to oxygen content distribution and inclusion count across the ingot section, the distribution of oxide residues along the ingot length is of great interest. Samples were taken for comparative evaluation from the top and bottom of 28 to 45-ton crankshaft forging ingots. For this investigation, 60 DHHU vacuum-treated ingots and 68 untreated ingots from three separate steel makers were used.

Fig. 12 shows oxide residues found in the ingot bottom plotted against oxide residues in the ingot top. Where the quantity was the same in the top and bottom of the ingot, the points lie on the bisection of the axes. Points below the line indicate higher oxide residues in the ingot top, and points above the line indicate higher oxide residues in the bottom.

For vacuum-treated steel, a maximum of 200 g per ton of oxide residues was found in the top of the ingot, and in the bottom of the ingot higher values were occasionally found. Compared with oxide residues in untreated steel, this investigation proves that vacuum treatment reduces the total oxide residues, provides greater uniformity over the ingot length, and a reduction in the difference from heat to heat.

Chemical uniformity

The results listed up to this point emphasize production uniformity as a particular characteristic of steels treated by the DHHU process. This proof is based on gas content, cleanliness rating, and the amount of oxide residues. Uniformity should also be considered from the point of view of chemical composition. In this connection, the distribution of elements with a high oxygen affinity—such as aluminum—is of prime importance.

Data for this purpose were gathered from samples taken from a total of 3500 tons of deep-drawing material destined for cold-rolled strip. Groups of 5-ton ingots were bottom teemed, and samples taken from the top, mid-section, and bottom of each ingot of the

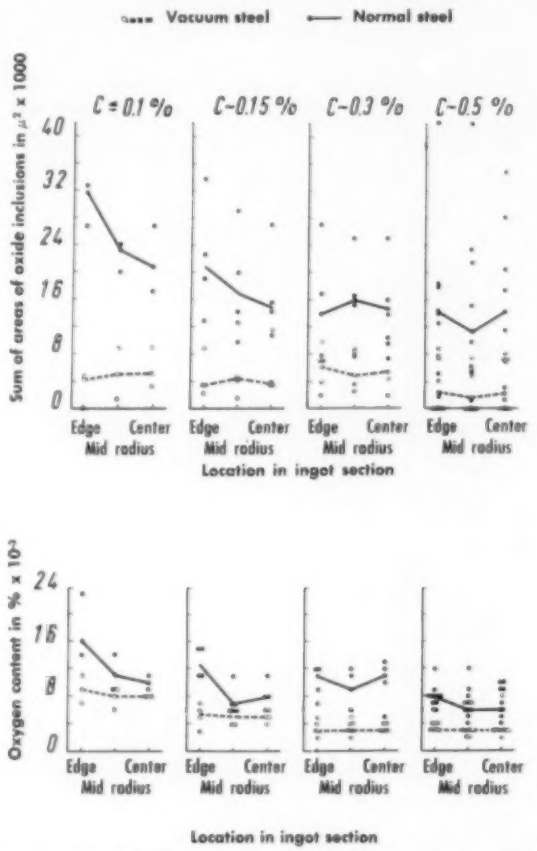

Fig. 11—Comparison between size of oxide inclusion areas for 0.55 sq in. (X100) and oxygen content for treated and untreated steel.

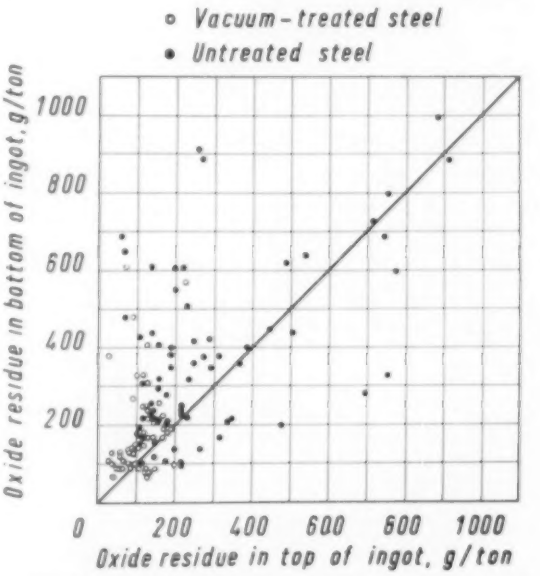

Fig. 12—Oxide residue in 28 to 45-ton forging ingots of unalloyed open-hearth steel with 0.45 pct C.

first and second group of each heat. The samples were then analyzed for aluminum content. The diagram on the left in Fig. 13 shows the distribution of deviations of specific values from the average aluminum content of each heat. None of the 50 vacuum-treated heats examined showed deviations larger than ± 0.002 pct Al between samples taken from the top, mid-section, and bottom.

Variation in average aluminum content among all 50 heats examined is shown in the right-hand diagram of Fig. 13. All heats indicated the same total quantity of dissolved aluminum. This uniformity would not have been possible without vacuum treatment. However, since the same aluminum addition per ton of steel was maintained, and because vacuum treatment established the same oxygen content in all heats before aluminum addition, all aluminum contents lie between 0.025 pct and 0.029 pct. This range is roughly equivalent to the accuracy of the analytic determination.

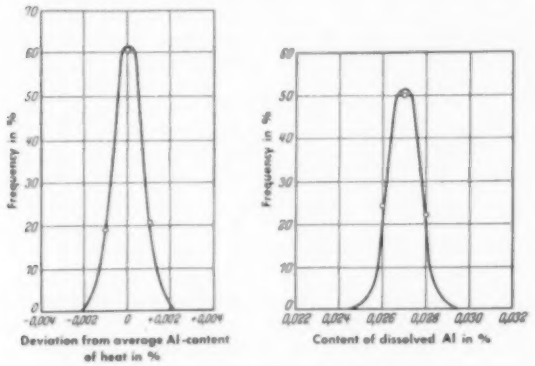

Fig. 13—Distribution of aluminum in 5-ton ingots of vacuum-treated deep-drawing steel.

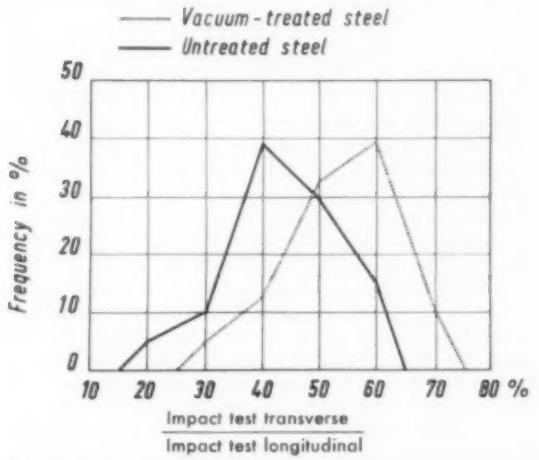

Fig. 14—Comparison of impact tests in transverse and longitudinal direction.

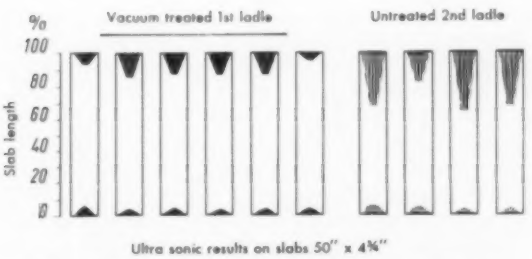

Fig. 15—Pipe formation in top and bottom of 10-ton slabs.

Mechanical properties

Uniformity of cleanliness and analyses creates uniformity in various mechanical properties. For example, the difference between longitudinal and transverse ductility are reduced. Several property evaluations were made, including a comparison of longitudinal and transverse impact strength. These tests were made on samples taken from the same ingot section used for the oxygen and micro samples, as can be seen in Fig. 7.

The correlation between transverse and longitudinal impact strength values is shown in Fig. 14. The most frequent values of transverse ductility were 40 pct of the longitudinal values for untreated steels and 60 pct for vacuum-treated steels. The improved correlation between transverse and longitudinal values for vacuum-treated steel, indicated in Fig. 14, was produced by the 50 pct average increase in transverse ductility.

Perhaps the most important single advantage of vacuum treatment is that a generally higher yield is obtained due to better welding of pipe during rolling. Fig. 15 shows the pipe configuration for rolled 10-ton slabs teemed from the first vacuum-treated ladle and the second untreated ladle from the same heat. All slabs were cast water-chilled. Ultrasonic tests of the slabs showed a significant reduction in depth of pipe in the end of the slab for vacuum-treated steel compared with untreated material. The average pipe depth in this test was 10 pct of the slab length for vacuum steel and 30 pct for untreated steel.

Conclusions

In this brief paper it has been possible to mention only a few of the improvements in quality and steelmaking practice that can be obtained with this vacuum treatment process. As with all new processes, more development work is needed to realize all the potential of the method. For example, one obvious possibility is that of desulfurization during treatment. Theoretically, the reducing conditions and the violent turbulence present in the vacuum vessel favor lime desulfurization. Work is in progress to establish a practical method for achieving desulfurization during treatment.

Work is also being done on the removal of oxygen and/or carbon from high-alloy grades which are inherently killed before treatment. According to published equilibrium values, it should be possible, at the pressures obtainable in the treatment vessel, to reduce the carbon content even in the presence of silicon. This effect could be increased by the use of oxidizing agents. Of course, this possibility can be established only by tests under operating conditions.

The advantages of vacuum treatment to the steel user should be considered. It is difficult to obtain complete data from customers, but increasing demand for vacuum-treated material and general discussion with users lead to certain qualitative assumptions: the vacuum treated product is more consistent and has better cold workability and machinability. Close contact is being maintained with the users of vacuum-treated steel and more detailed results will be available in the future.

DISCUSSION, The DHHU Process

by E. A. March

The vacuum degassing unit being installed at the Midland works of the Crucible Steel Co. of America is of the same basic design as the unit described in the foregoing paper. Our melt shop consists of a single long building housing one 35-ton electric furnace, four 80-ton electric furnaces, and nine 170-ton stationary open hearths. Our degassing unit will be located on the furnace working floor between the electric furnaces and the open hearths. Ladles of steel will be brought under the degassing unit by means of a transfer car moving between the pit bay and the furnace bay of the building.

This unit, being constructed by the Lectromelt Furnace Div. of the McGraw-Edison Co., will be the first of its kind installed in the US. It will be a flexible unit capable of treating the complete product from any of the three furnace sizes found in our shop. The 170-ton open hearth ladles will rest directly on the ladle car, while the smaller electric furnace ladles will rest upon adapters to bring the metal line to the same height, regardless of which size ladle is being treated. Treated steel will be transferred back to the pit bay and teemed in the normal manner.

The vacuum vessel itself is 15 ft max diam by 14 ft 9 in. high. The entire inner lining will be magnesite (93 pct MgO, 3 pct CaO). The nozzle will have refractory lining on both inner and outer surfaces. The inside diameter will be 25 in. There are five additions hoppers on top of the vessel, all capable of discharging ferro alloys into the vessel while under vacuum. There are two hoppers of 80 cu ft capacity, two of 20 cu ft capacity, and one of 10 cu ft capacity. Within the hoppers, there are combinations of small chambers to allow precise heat chemistry adjustment. The vessel will raise and lower hydraulically, traveling about 6 ft at a speed of about 20 ft per min. During operation, normal movement is about 2 ft.

There is a graphite resistance rod approx 8 ft long across the top of the furnace, supplied by 750 kva of single-phase power. The purpose of this rod is to maintain the temperature of the refractories at that of liquid steel and, therefore, to compensate partially for the heat loss during the process.

The vacuum will be achieved by means of a four-stage steam ejector rated at 130,000 cfm of evolved gas at average density and 200°F. In addition to this, a parallel evacuator permits initial pump-down in less than 30 sec. After use, the vessel is flooded within 15 sec with N_2, requiring about 10 cu ft at 40 atm.

E. A. MARCH is assistant works manager, Crucible Steel Co. of America, Midland Works. This discussion was presented at the 1960 AIME National Open Hearth Steel Convention.

The majority of our open hearth shop's product is in the range of 0.20 to 0.45 pct C and in alloy grades. We expect to tap unblocked heats at carbons slightly higher than specification . . . move these to the degassing unit . . . and cycle the metal through the vacuum chamber where the O_2 will react with the C to result in a violent boil and the concurrent removal of all gases. When degassing is completed, alloy additions will be made through the vessel during the last few cycles. Calculations, based upon the experience at Dortmund and upon our equipment capabilities, indicate that a total of 30 to 40 cycles will complete the process.

Interpretation of the paper's data concerning quality improvement is very difficult. We can only state that our examination of samples from Dortmund verifies the fact that there is a very definite improvement in non-metallic inclusion count through degassing. Oxides are slightly reduced in number, considerably reduced in maximum size, and their distribution is somewhat more uniform. Silicates are reduced to an even greater degree. Even sulfides seem to be redistributed so that, while sulphur content remains essentially unchanged, the sulfides become smaller, more numerous, and more uniformly distributed. The open hearth product plus degassing is expected to show a significant improvement over present product.

Having within Crucible the capability of producing steel by the open hearth, electric arc, air induction, vacuum induction, and vacuum arc methods, we are not yet certain just where vacuum-degassed steel will fit into the picture. We do not know which of these processes will be augmented by vacuum degassing, which will be supplemented, or which will be replaced. European experience to date has been entirely with open hearth products. It seems ideal for these. At the next Open Hearth Conference, we will be able to present the results of our work.

Please bear in mind that our objective is somewhat different from that of those firms which have installed stream degassing units. We do not have a major problem requiring hydrogen removal in our products. We must achieve quality improvements in non-metallic inclusion ratings, magnaflux ratings, and, possibly, in transverse properties. This unit seems to possess the requisite characteristics, since we can degas and then make alloy additions. There are interesting possibilities of using this equipment to produce carburizing grades, alloy grades, and even traditionally electric furnace grades in the open hearth.

SAVINGS THROUGH EXOTHERMIC FERROCOLUMBIUM

by T. W. Merrill

THE addition of columbium as ferrocolumbium to high alloy steels is considered to be a relatively critical operation. In the first place, ferrocolumbium dissolves rather slowly in steel, even though it is normally added as particles of ½-in. diam or less. Also, because ferrocolumbium has a greater density than many alloys, the particles sink to the bottom of the furnace ladle. Secondly, ferrocolumbium oxidizes readily when in contact with an oxidizing slag, or when exposed to air at elevated temperatures. As a result, the actual recovery of columbium in making Type-347 stainless steel ranges from 70 to 85 pct.

In electric furnace steelmaking, ferrocolumbium is generally added to the furnace through a suitable refining slag. This is done some 30 min prior to tapping in order to allow time for the alloy to dissolve completely in the bath. During this period, it is vital to stir the bath vigorously in order to achieve an adequate recovery of columbium.

Some steelmakers add part of the ferrocolumbium to the furnace and part to the ladle. Another method is to add all the alloy in the ladle. In all but the latter case, additional furnace time is required, and, presumably, a somewhat higher temperature is needed to insure solution of the alloy.

These inconveniences and disadvantages suggest the use of exothermic ferrocolumbium in the making of columbium-bearing steels.

Laboratory work

After preliminary work with various exothermic mixes, it appeared to metallurgists of the Vanadium Corp. of America (VCA) that a sodium nitrate-ferrosilicon type might perform satisfactorily. The manufacture of such a mixture involves crushing ferrocolumbium to a screen size of −8 mesh, mixing sodium nitrate to the extent of 10 pct of the mixture weight, and adding 5 pct ferrosilicon (75 pct Si) of −200 mesh size. An organic binder is also added to insure close association of the ingredients. The mixture is packed in steel cans—small ones for induction-furnace melts and larger ones for arc-furnace heats.

The mixture was given preliminary evaluation at the VCA Research Center by adding it to a number of heats of Type-347 stainless steel. The first trials were run with 300-lb induction-furnace heats. These were made by melting Armco iron, electrolytic nickel, and low-carbon ferrochrome, to which electrolytic manganese and ferrosilicon were added. Final deoxidation consisted of adding 0.10 pct Al to the bath. Just before tapping, a sample was taken for chemical analysis. The exothermic mixture, packed in one small metal can containing columbium equivalent to an 0.80 pct addition, was placed in a heated ladle, and molten metal was tapped onto it. A hot, vigorous reaction took place, which was completed before the tap was finished. The temperature of the metal at tap was 2950°F. Several small ingots were poured and later drilled for chemical analysis.

For a further evaluation of the exothermic mixture, a 3000-lb arc-furnace heat of Type-347 stainless steel was produced. Plate scrap, electrolytic nickel, and low-carbon ferrochrome were melted, and the heat was deoxidized with ferrosilicon and 0.10 pct Al. The original calcium-silicate slag was not replaced. For the 0.80 pct Cb addition, a single can of exothermic ferrocolumbium mixture was dropped into the ladle just as the heat started to tap. The tapping temperature was regulated to compare with that of a commercial heat. The reaction of the exothermic alloy was not considered to have been any more violent than that experienced when adding exothermic ferrochromium under similar conditions. The heat was poured into 12x12-in. cast-iron molds which, when cooled, were drilled for analytical samples.

Test results

Analyses of the various heats showed that the columbium recovery from the exothermic mixture was above 90 pct; the small heats showed 97 pct recovery or better, and the arc-furnace heat 92.5 pct. Table I shows the average composition of five 300-lb induction heats and the one 3000-lb arc furnace, as well as the columbium recoveries achieved.

Savings shown

The use of exothermic ferrocolumbium as a ladle addition makes it possible to eliminate the furnace time required when using regular ferrocolumbium. In addition, this alloy mixture permits the steelmaker to take advantage of any residual columbium that may be present in the bath, thus reducing the possibility of off-analysis heats.

Savings per ton will vary, of course, with the individual case. But a typical 10 pct increase in recovery of columbium results in savings as high as $7 per ingot ton.

Table I. Test Results of Exothermic Ferrocolumbium Additions to Five 300-lb Induction Heats and One 3000-lb Arc-Furnace Heat

	Composition, Pct						
	C	Mn	Si	Cr	Ni	Cb	Ta
Aim	0.08	1.50	0.50	18.00	9.00	0.80	—
Induction, Avg Five Heats	0.09	1.38	0.54	18.30	9.07	0.78	0.02
Arc Heat	0.19	—	—	15.88	8.17	0.74	0.006

	Columbium Recovery		
	Cb Added, Lb	Cb Recovered, Lb	Cb Recovered, Pct
Induction, Avg Five Heats	2.40	2.34	97.4
Arc Heat	24.00	22.20	92.5

T. W. MERRILL is a metallurgical engineer with the Vanadium Corp. of America.

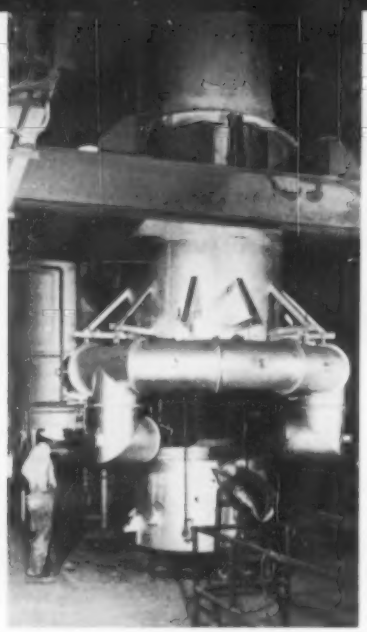

Fig. 1—Bruceton's experimental blast furnace.

IRON, STEEL, AND FERROALLOYS INVESTIGATED AT BRUCETON

by Norwood B. Melcher

While the US Bureau of Mines' research in iron and steel is widely scattered through 22 institutions, work done at the Bruceton Pyrometallurgical Laboratory in Bruceton, Pa., has been responsible for many important steps forward in iron and steel technology. This is a review of the work and a description of the laboratory written by its Director.

A Pyrometallurgy Laboratory of the US Bureau of Mines is located at Bruceton, Pa., near Pittsburgh, and functions administratively as part of the Bureau's new regional Metallurgy Research Center at Minneapolis, Minn. The Pyrometallurgy Laboratory is responsible for conducting research and preparing reports on projects related to the production of iron, steel, and ferroalloys.

The program takes two directions: process metallurgy and fundamental research. In process metallurgy, ferrous metals are extracted from their ores by using furnaces modeled on their industrial counterparts; this constitutes the major activity in terms of man-hours of research. Fundamental research is aimed at determining basic properties of molten metals and slags and in developing alloys.

The Laboratory is financed by the Federal Government, but the cost of certain projects may be shared by industry. Such projects must be of mutual interest and also must be of broad national significance.

Although some of the Laboratory's equipment may seem large for research purposes, the Bureau believes it to be minimum size for obtaining reliable data. Major furnace equipment is listed in Table I.

The Pyrometallurgy Laboratory employs 95 people, 23 of whom are professional, including analytical and physical chemists, metallurgists, a physicist, and a mechanical engineer. Also included in the professional group are four student trainees who assist in the research as their academic work permits. The leaders of technical research and their fields are listed in Table II.

The process laboratory is housed in a building consisting of a main area 178-ft long and 50-ft wide with north and south wings. The principal furnace area is 128-ft long and 50-ft wide. This area contains an experimental blast furnace and an open-hearth at opposite ends of a pouring pit. A 1-ton electric-arc furnace and a pig casting machine also are in this area. In the north wing are a vacuum induction melting furnace, an 8½-in. rolling mill, and a 1100-lb forging hammer. The south wing houses a rotary kiln and a recuperator that is used to preheat air for kiln and open-hearth operations.

A charging area for the blast furnace is outside the building. In this 6700 sq ft area there are raw material bins, hoppers, scales, a skip, and a gas-cleaning system. Rail shipments of raw materials are received on a siding serving the Laboratory. Portable belt conveyors are used to move raw materials from hopper cars to trucks for transport to an ore yard or storage bins.

Offices, an analytical laboratory, and laboratories for small-scale furnace work, metallography, and mechanical testing are in a nearby building. This structure has an area of 11,000 sq ft.

The chemical laboratory provides analytical service for research projects and also performs separate studies involving improved analytical methods and techniques. Chemical analysis of the charge materials and products is required for estimating compositions and yields and also for relating process operations.

The experimental nature of the cooperative projects involves investigation or development of methodology so that new or unusual analytical problems can be solved. A rapid method for determining lime, magnesia, and titania in blast furnace slags and other calcareous materials has been developed. Another attainment has been the development of a way to obtain the average composition of blast furnace top gas over various specific intervals.

Blast furnace research

Activity in blast furnace research is directed toward developing improved operating techniques and evaluating new or unusual types of raw materials. The operations of each project are carefully planned—so that results will be indicative of the response one may expect if used in a commercial operation.

Cooperative research is encouraged and has been undertaken with several industrial groups on phases

NORWOOD B. MELCHER is research director, Minneapolis Metallurgy Research Center, Bureau of Mines, US Dept. of Interior.

of blast-furnace smelting. The heart of this research is the experimental blast furnace and its auxiliary equipment. The furnace and the operating procedures have been developed to a point that the furnace can consistently yield results reliable for translation to commercial practice. A general view of the furnace is shown in Fig. 1. The regenerative stoves supply hot blast to the furnace at temperatures as high as 2500°F. The hot-blast main and bustle pipe, the goosenecks, and the blowpipes are brick-lined and insulated to assure satisfactory life and a minimum of heat loss.

In addition to the stoves, auxiliary equipment includes a rotary blower to supply the air blast . . . a single-skip hoist for moving raw materials to the furnace top . . . floor scales for weighing all materials before charging . . . and storage bins and feeder belts for serving weigh cars that dump into the skip. A storage hopper is equipped for drying coke. The gas-cleaning system consists of a primary dust catcher and an orifice-type wet washer in an electrostatic precipitator in series.

Slag is flushed into pots. Casts are run into brick-lined ladles from which the slag is decanted into pots and the iron is cast into pigs on a casting machine.

Instrumentation is provided for recording and controlling the significant variables affecting furnace operations: air-blast rate, blast temperature, stove heating cycle, blast humidity, and modifications of blast composition with oxygen, steam, and natural gas. Blast temperature is controlled by automatically regulating the proportion of the metered cold blast that bypasses the stoves. Stove change-over takes place automatically when the flue gas from the stove being heated reaches a set temperature, usually 425°F. Indications of furnace performance which are recorded continuously include tuyere pressure, top pressure, top gas composition, and temperatures within the stock column.

This furnace can be operated in an unorthodox manner—and often is—so almost any desired operating condition can be attained. Such experimental operations, of course, are impractical for industrial furnaces. Should the imposed conditions in the experimental unit be so severe that operations cease, a detachable hearth on the furnace provides ready access for cleaning the stack and reconditioning it. Operations usually are resumed in only two or three days.

Smelting operations in the experimental blast furnace have covered a broad field of attack. Thus far, projects have concerned evaluations in the following fields: iron sources, agglomerated burdens, fuel sources, blast composition, and production of special furnace products. Concurrently, considerable work also has been carried out to learn more about the blast furnace process itself.

Problems regarding the sources of iron and the related questions of their size consist and agglomeration have been studied. During the past dozen years, many of the ores domestically consumed for basic iron production have been evaluated. Against this background, materials from several prospective ore sources likewise have been smelted. For the latter purpose, the experimental furnace is invaluable because operations upon a few carloads of ore will, in the period of a week or two, provide a good basis for predicting the minimum coke rate, maximum wind rate, and the operating peculiarities of the material. Akin to ore evaluation has been a large amount of work concerning the effects of ore and coke-size composition, for it is no problem to provide sufficient materials to as narrow a size range as desired, or to blend materials of various sizes. All the commercial pellet products have been smelted in the experimental furnace, as well as hard and soft sinters from several plants, self-fluxing sinters, several types of custom-made pellets, and even raw pellets of ground taconite. Recently, even a fine ore, as received, was smelted.

Fuels studied have included several eastern cokes, western coke, and anthracite. Research in this area has been stepped up in the past two years. Extensive development work has been completed on the use of natural gas, injected through regular and auxiliary tuyeres, as a replacement for some of the coke.

Together with this work, studies in using tuyere-injected steam and oxygen to increase blast furnace production rates have been conducted. The use of natural gas resulted in blast furnace production rate increases of more than 25 pct, with a comparable saving in coke consumption. The process has been adopted commercially. Research in the field of fuels has established the advantages that can be obtained through the use of high hot-blast temperatures. Table III gives information obtained in recent studies of effects of blast composition.

Production of special furnace products has been undertaken since the beginning; indeed, the first furnace (the present furnace is the third generation)

Table I. Major High-Temperature Furnace Equipment—Pyrometallurgy Laboratory

Equipment	Description
Blast Furnace	4-ft-diam hearth; three tuyeres; 21 ft-4-in. tuyere to stockline; two Royster pebble stoves Production: 15 to 30 tpd
Open-Hearth Furnace	4-ton capacity, recuperative, basic-lined, tilting, gas-fired
Rotary Kiln	5-ft ID, 9 ft-6 in. long; gas-fired
Vacuum Induction Furnace	50- or 100-lb capacity, 50-kva motor generator; pressure range 5 psig to 1μ Hg, 10-in. booster pump
Electric-Arc Furnace	three-phase 500-kva, basic-lined, 1-ton capacity
Fundamental Research Furnaces	two molybdenum resistance furnaces, 5-kva, 1 carbon resistance furnace, 12-kva

Table II. Supervisors—Pyrometallurgy Laboratory

Warren M. Mahan Project Coordinator	Process metallurgy
J. P. Morris Project Coordinator	Basic research
Richard J. Leary Supervising Extractive Metallurgist	Steelmaking and scrap treatment
David J. Kusler Supervising Chemist	Chief chemist
Edward J. Ostrowski Supervising Engineering Technician	Iron blast furnace research
Sergius D. Andreychek General Engineer	Facility design, installation and maintenance

Table IV. Effect of Injection of −18 mesh Anthracite on Metal and Slag Compositions of a 2900-lb Experimental Open-Hearth Heat

	Carbon Injected, Pct of Metal Wt	Carbon Recovered in Metal, Pct	Metal Analysis, Pct			Fe in Slag, Pct
			C	P	S	
Prior to injection	—	—	0.15	0.021	0.060	7.0
Injection No. 1	1.17	61	0.86	0.017	0.065	9.5
2	0.58	51	1.17	0.010	0.069	11.5
3	0.58	46	1.40	0.015	0.066	9.7
4	0.58	61	1.76	0.016	0.070	8.0

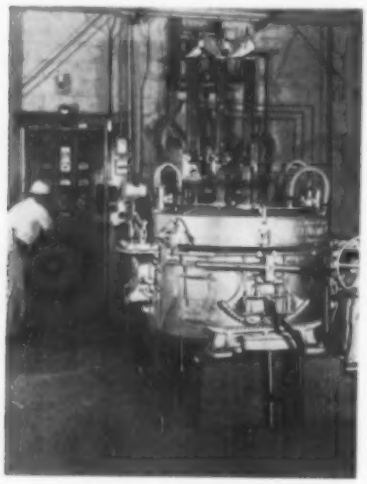

Fig. 2—1-ton electric arc furnace at Bruceton.

was constructed to smelt open-hearth slags and low-grade manganese ores to recover manganese. Later, laterite ores were smelted to recover nickel. More recently, a smelting procedure was worked out to produce a slag containing approximately 50 pct alumina for cement clinker and quality iron as well.

Along with such work, the Bureau continues its studies of the blast-furnace process. Perhaps best known has been the nitrogen quench of the stock column and its subsequent examination. Studies of gas velocity distribution, pressures, temperatures, and gas composition of the column also are being investigated. Material and heat balances are calculated for each operating period.

Steelmaking

Steelmaking technology has played a prominent part in the Laboratory's research—even since the earliest days of the Bureau of Mines. In 1914, four years after creation of the Bureau and scarcely eight years after the first electric-arc furnace began operating in this Country, the Bureau published a 142-pp report on electric furnaces for making iron and steel. Research into alloy steels during World War I helped pave the way for using molybdenum in engineering and constructional alloy steels. The Bureau's pioneering work in applying the principles of physical chemistry to steelmaking problems and in demonstrating the relevance of their researches to the development of sound steelmaking practices also are significant. During World War II, the Bureau's continuing interest in developing processes to meet national needs resulted in development of a rotary-kiln process capable of producing sponge iron sufficiently low in sulfur to provide a suitable synthetic scrap charge for steelmaking furnaces.

In recent years, efforts have been directed toward innovations in steelmaking processes aimed at increasing the rate of output from commercial furnaces. Since these units are characteristically batch-type, the underlying notion has been to raise output by diminishing the furnace period required to produce a heat. For this research, as with the experimental blast furnace, the Bureau finds it desirable and necessary to perform the experiments in furnaces that are large enough to give the scientist a glimpse of the operating difficulties that may arise when the experimental process is undertaken in full-size industrial units. The first factor concerns the designing of the experiment so that results can be extrapolated. The second factor requires that the technique of operation be developed to the point where it is evident that the same results can be accomplished on an industrial scale. Hence, the Bureau has a 4-ton open-hearth and a 1-ton arc furnace. The 1-ton furnace is shown in Fig. 2.

This work has concentrated on developing new techniques that would constitute rational improvements. One has been the pneumatic injection of solids, such as carbon to recarburize soft melts, iron ores for rapid decarburization, and certain alloying agents. This method is rapid, efficient, and susceptible to automatic control. Table IV shows results of this technique when using anthracite for recarburizing. Another project has centered on the convective preheating of scrap and other materials before charging them into arc furnaces. This is a good example of utilizing heat of fuel combustion and electric-arc heating—under conditions in which each material functions best.

Current research emphasizes four areas: 1) refining and casting factors affecting the forgeability of steels; 2) oxygen refining of pig iron in the blast furnace runner; 3) upgrading steel scrap contaminated with nonmetallics and nonferrous metals; and 4) effect of rare earth metals upon mechanical and other service properties of high-temperature alloys.

Ferroalloy research

Ferroalloy research has been chiefly concerned with the recovery of nickel, cobalt, and chromium from laterite and serpentine ores and with the recovery of manganese from open-hearth slags and off-grade ores. A process for recovering manganese from open-hearth slags and ores, as developed by the Pyrometallurgy Laboratory, is a three-step method involving smelting in the blast furnace to

Table III. Optimum Data Determined During Experimental Blast Furnace Runs Using Same Burden Materials With Various Blast Compositions

	Blast Enrichment						
	Wind Rate Std. Cfm	H_2O (Grains Per Cu Ft)	Pct of Air Blown CH_4	Pct of Air Blown O_2	Hot Blast Temp, °F	Coke Saving Per Ton Pig Iron, Pct	Production Rate Increase, Pct
Base period	800	6.1	—	—	1800*	—	—
Stream additions	800	26.6	—	—	2475	6	22
Methane additions	800	5.5	4.64	—	2475	22	21
Methane and oxygen additions	800	6.2	4.56	2.44	2475	23	35

* Hot blast required under conditions of minimum operable coke rate.

spiegeleisen . . . selective oxidation in a basic-lined converter to produce a high-grade synthetic manganese ore . . . and smelting to standard ferromanganese. Byproducts include high-grade melting stock for steelmaking and high-phosphorus-bearing slags suitable for fertilizers.

Nickel research had two objectives: to determine if specification-grade nickel could be made from nickel oxide produced at the US Government-owned plant at Nicaro, Cuba, and to obtain melting stock for stainless steel from laterite and serpentine ores.

A successful procedure was developed to convert Nicaro nickel oxide to nickel metal. Sponge nickel was produced in a rented, commercial, circular, gas-fired tunnel kiln, and then melted in the Bureau's 4-ton basic open-hearth furnace. Two slags were used to remove impurities and lower the cobalt content to specification. Table V shows the average grade of sponge nickel and refined nickel metal produced by this method.

Various methods were tried to reduce, selectively, the laterite and serpentine ores—including selective reduction and reduction of nickel from molten ore passed over a bath of molten iron. Research revealed that iron could readily be oxidized from an iron-nickel alloy to upgrade the nickel and to create a suitable base melting-stock for stainless steel.

Another approach in using low-grade nickel ores was to produce liquid iron containing 3 to 6 pct Ni in a rotary kiln. This metal was blown (in a basic-lined converter) to an iron-nickel alloy containing 12 to 15 pct Ni.

Present chromium research is designed to produce a synthetic chrome ore with a high chromium-to-iron ratio of 3:1 to 10:1 by smelting off-grade chromites and following this with the selective oxidation of the chromium.

Basic research

Basic research chiefly involves physical chemistry, with emphasis on determining activity coefficients of the constituents of iron's liquid alloys. Knowledge in this area is quite meager, largely because of a lack of satisfactory experimental techniques. More information is needed so that full benefit can be derived from applying the principles of physical chemistry to problems in ironmaking and steelmaking.

Completed projects in this field include measurements of the activity coefficient of sulfur dissolved in liquid iron and the effects of silicon, carbon, and manganese on sulfur activity in the corresponding ternary alloys. The measurements were made by determining the conditions of chemical equilibrium between an alloy and a hydrogen-hydrogen sulfide mixture. In conducting the experiments, the Bureau bubbled the gas mixture through the metal by using an impervious capillary alumina tube.

One interesting result of the research on sulfur was the discovery that the reaction between the incoming gas and the metal was very rapid and equilibrium was attained during the brief period of contact. This observation was applied later in developing a method for measuring vapor pressures of liquid metals. When a stream of inert gas is bubbled through a liquid metal or when a jet of the gas is impinged on the metal surface, the gas becomes saturated with vapor. By condensing out the metal vapor from a known volume of the saturated gas, the vapor pressure of the metal can be determined. The method permits the measurement of vapor pressures with values of 0.01 mm of Hg and lower, a range not covered by high-vacuum techniques.

Table V. Avg Grades of Nickel Oxide Treated and Nickel Sponge and Ingots Produced

	Analyses, Pct		
	Ni + Co	Co	S
Nickel Oxide	76.91	0.91	0.01
Nickel Sponge	92.50	1.01	0.072
Nickel Ingots	98.54	1.00	0.059

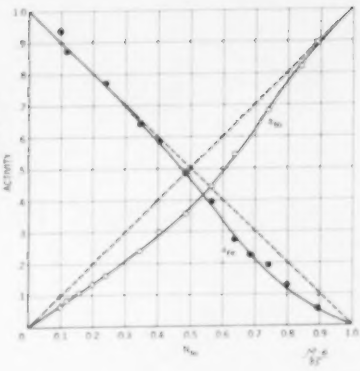

Fig. 3—Activities of iron and nickel in Fe-Ni alloys at 2912°F, as a function of the mole fraction of nickel.

This method has been applied successfully to liquid iron, nickel, copper, and manganese and to iron-nickel, iron-copper, and iron-manganese alloys. The vapor pressures obtained for the alloy systems were used to calculate the corresponding activity coefficients. The results obtained in the investigation of the iron-nickel system are shown in Fig. 3. Prior to this work, it was generally thought that iron-nickel alloys formed ideal solutions. Present work in this field covers the effects of carbon, silicon, and other elements on the activity of manganese in iron.

In addition to the vapor pressure and activity studies, the Bureau now has equipment for measuring heat contents of liquid metals and slags. A high-temperature furnace and diphenyl ether calorimeter are used. The initial application will be to blast-furnace metal and slag, but work on pure metals also is planned.

Coordinated approach

The unique arrangement of process furnaces representing all the major iron and steelmaking processes under one roof encourages a coordinated approach to process research. The presence of basic research in the program also brings an appreciation of fundamental relationships to the process program. In turn, basic research is guided, in part, by gaps in such information that become evident during the evaluation of process projects. A collateral, yet important, benefit of the process research is a seasoned familiarity with and respect for the practical aspects of furnace operation that arises from the experience gained in designing and constructing, then operating and maintaining, the furnaces and auxiliary equipment. The broad look, the deep view, and the down-to-earth perspective each helps strengthen the pertinence of today's research to the conditions that will face operating management tomorrow.

Electron Beam Welding

by Clyde M. Adams, Jr. of Massachusetts Institute of Technology

The electron beam is fast gaining recognition as a unique, high-vacuum heat source for processing materials . . . finding application in the drilling, cutting, refining, and welding of metals and non-metals . . . and showing promise in coating, cladding, and casting. First applied to welding by K. Steigerwald of Carl Zeiss in West Germany about 1950, several US firms are currently developing and manufacturing electron beam welding equipment.

The electron beam is unique as a processing heat source by virtue of its intensity (over 10,000°F), focusing ability, and high vacuum (0.03 to 0.05 μ) operation. This combination clearly distinguishes the electron beam from arc, induction, or resistance heating. Before the electron beam, there was no means of performing conventional fusion welding in a high vacuum with a moving heat source—the closest approach being dry-box equipment in which an arc is sustained in a chamber filled with purified inert gas. In this sense, many regard the electron beam as the ultimate dry box.

Operation

The principle of operation is that of the cathode-ray tube, wherein a heated tungsten filament is the cathode from which emitted electrons are accelerated toward an anode, using a potential difference of 5000 to 150,000 v. In some welding equipment, the anode is the workpiece itself, an arrangement common to many zone-refining or drip-melting operations. However, recent equipment has incorporated an integral ring-shaped anode through which most of the electrons are accelerated, and after leaving the region of steep potential gradient they travel at constant velocity toward the workpiece. The tendency for the beam to diverge electrostatically after passing through the anode is overcome by electromagnetic or electrostatic focusing. The workpiece and the anode are usually at the same (ground) potential.

There are two major reasons for having the anode separate from the workpiece: 1) filament life is improved, not only because the filament is geometrically remote from the workpiece—which is the primary source of contamination—but also because there is no electrostatic field to accelerate the positive ions produced by bombardment of the workpiece toward the filament; and 2) operative control is improved since the electron beam can be directed within recesses or re-entrant angles in the workpiece without seeking the shortest path.

There is also a choice to be made as to the type of focusing employed. **Electromagnetic** focusing accords some advantages in circuitry and control, but for high-power operation, the focusing coils are necessarily somewhat massive and require water cooling. In **electrostatic** focusing, a secondary circuit is required to maintain the relatively low positive-potential of the focusing apertures, but these apertures may be of light construction and render more feasible the movement of the gun for automatic welding within the vacuum chamber.

Joint preparations and welding procedures are still somewhat primitive, primarily because automatic wire-feed mechanisms have not been incorporated into electron beam equipment. To date, simple co-fusion of the members to be joined has been the rule with filler, if any, being first placed along the intended seam. There is no reason to doubt that cold feed metal techniques eventually will be applied to electron beam welding, although more quantitative information on the over-all thermal characteristics of the beam as a moving heat source must precede the evolution of firm welding procedures.

There is some controversy as to the optimum voltage range for electron beam equipment. For a given power input, the higher the voltage, the narrower is the heat source and the deeper the penetration. Thus, high voltage looks attractive for drilling, cutting, or joining of thick members. (The deep, narrow fusion zones produced at very high voltages bear some similarity to brazed joints.) At the other extreme, relatively low potentials (5,000 to 10,000 v) can be used quite successfully for refining operations in which focusing is relatively unimportant. Weld fusion zones of shapes similar to those produced in permanent electrode arc welding are obtained in the range of 15,000 to 30,000 v and 1 to 8 kw. For welding, the low-voltage equipment is attractive from several standpoints: 1) low-cost power supply, 2) short wave-length X-rays are not produced, and 3) equipment and insulation are substantially less massive. The governing technical relationship in selecting voltage is that the minimum beam cross-section (in the focused region) is proportional to beam amperage, so that high power and narrow focusing can be achieved only at high voltage. However, in the many applications in which fusion zone widths of 0.050 to 0.150 in. are tolerable in stock thicknesses of less than 0.300 in., potentials as low as 15,000 v will find application.

Applications

The intensity of the heat source and the purity of the environment have directed much current attention to welding reactive and refractory metals. In addition, the process deserves attention for application to ultra-high-strength steels in which the complete absence of hydrogen is so essential to the consummation of a successful weld. Some difficult pneumatic problems have been solved using the electron beam welder for encapsulation; in fact, the biggest current commercial application is in sealing nuclear reactor fuel elements. Many of the most attractive characteristics have yet to be exploited. For example, by defocusing, the beam can be used for pre- or post-heat treatment in association with welding and offers much potential for vacuum brazing.

The future of the electron beam for welding is definitely not confined to the laboratory. Size is no real limitation, since large vacuum chambers have become virtually commonplace, and, in fact, a large vacuum reservoir is an advantage in electron beam welding where outgassing is likely to be irregular. It is of interest that the process is fail-safe against accidental weld contamination, since the electron beam becomes inoperative at pressures above 1 μ. When more utilitarian and maneuverable equipment is developed, the electron beam will become a serious contender for many critical joining applications in which the refining and high intensity inherent to the process can offer any advantage.

1960 AIME ANNUAL MEETING

TIME: February 1960

PLACE: Sheraton-Atlantic Hotel . . . formerly Sheraton-McAlpin . . . formerly McAlpin . . . formerly?

OCCASION: 1960 AIME Annual Meeting

Gathering together from all corners of America, and many foreign lands as well, came 1076 metallurgists as The Metallurgical Society's contingent for the Annual Meeting. With the usual array of pre-convention committee and board meetings well underway, the Annual Meeting was launched Sunday afternoon, February 14th, when industry and educators took opposing views on the Terminal BS Program in Metallurgical Engineering. Two articles arising from this session are published in this issue, but we wish we could have captured the spirited discussion which ensued—seeming to point to an actual closeness of views between academic and industry representatives.

Meeting registration was heavy on Monday, February 15th, as metallurgists closed in on the Sheraton-Atlantic. Three symposia were perhaps particularly in the minds of many registrants. One, **Metallurgy in the Navy,** presented in considerable detail the metallurgical research program of the Navy, which is designed to meet the ever-mounting materials requirement of today's armaments. A great deal of very interesting information was divulged at this day-long Institute of Metals Division meeting. It will be published in the JOURNAL OF METALS within the next few months. This is the first in a series of symposia to be presented by The Metallurgical Society in an effort to increase communication between military and civilian scientists. The next such forum, to be held during the Fall Meeting of The Metallurgical Society, will be devoted to the Army; the third, at the 1961 AIME Annual Meeting, will be concerned with the Air Force.

The second interest-arousing symposium was the **International Symposium on the Extractive Metallurgy of Copper, Nickel, and Cobalt.** Much heretofore undisclosed information on processes and plants was discussed during this series of meetings. In the March issue, four papers were published covering nickel smelting operations in Canada, New Caledonia, Oregon, and Cuba. The complete text of all papers and discussion will be available later this year as one of the books published for The Metallurgical Society by Interscience Publishers, Inc. A brief summary of several of the copper, nickel, and cobalt sessions is given at a later point in this article.

The two ISD sessions on **Acid Converter and Basic Oxygen Steelmaking** drew wide attention as well. The papers on the new steelmaking processes will be published in JOURNAL OF METALS' special July issue on oxygen steelmaking.

Paul G. Shewmon (left) receives congratulations from 1959 AIME President Howard W. Pyle on winning the 1959 Alfred Noble Prize.

WELCOMING LUNCHEON

Other than technical sessions, the highlight of Monday's schedule was the All-Institute Welcoming Luncheon held in the Grand Ballroom of the Statler-Hilton Hotel. Howard C. Pyle, 1959 AIME President, presented the people at the head table to the overflow audience. Canadian Institute of Mining and Metallurgy president John C. Sproule next brought greetings from our sister society across the border. Awards for Student Prize papers were then presented. The 1959 Student Prize Paper sponsored by the Undergraduate Division of The Metallurgical Society was won by Leo A. Rogers, University of Utah, for his paper *Spectrophotometric Analysis of Niobium.* President's Banner Awards were then given for the sections achieving the greatest increase in membership over the past year. Pittsburgh section won the Group "E" award. Missouri School of Mines and Metallurgy took the top student chapter award. (See p. 419 for the story).

Luncheon speaker was John W. Vanderwilt, President, Colorado School of Mines. His subject: *Problems of Engineering Manpower.* Dr. Vanderwilt called for a thorough reappraisal of engineering education in order to produce graduates well versed in the theoretical aspects of metallurgy. He also urged the schools and industry to cooperate in inducing persons to enter the field by demonstrating the need for them.

HOWE MEMORIAL LECTURER

Tuesday, Feb. 16th, was the occasion for the Howe Memorial Lecture, always an event of note at AIME Annual Meetings. The Iron and Steel Division lecture was this year given by Robert F. Mehl, currently acting as a scientific liaison in Europe for the U.S. Steel Corp. *Commentary on Metallurgy* was the topic of Dr. Mehl's speech. The shortcomings and needs of the profession were cited by the Carnegie Institute of Technology professor. "In large-scale engineering research and development, especially in the extraction of metals and the form-

Outgoing . . . Incoming . . . Elect—those are the presidential titles borne by (left to right) Howard W. Pyle, 1959 AIME President; Joseph L. Gillson, 1960 AIME President; and Ronald R. McNaughton, AIME President Elect for 1961.

ing of metals we have, in recent years, too little to boast about in this Country!" he exclaimed. "More comes from abroad than one likes to contemplate. Really large-scale steel mill research and development have been in general undernourished. The Russians, Germans, and Austrians have done great things that we should have done . . .

"One can climb the scale in the magnitude of possible research and development effort, at least in imagination: a purely experimental, integrated steel mill, a dream of the ambitious development engineer, is in Russia, not here . . . Should there not be cooperative research to bear the tests of such large efforts? . . . "

Dr. Mehl went on to say that "the newer metals have, for the most part, come from the efforts of the chemical industry, not the metallurgical industry. One wonders whether the field of extractive metallurgy might pass out of the hands of the metallurgist and be taken over by the chemist, and especially by the chemical engineer, i.e., the field of chloride chemistry. This is a real challenge to the metallurgical profession. Industry has been lax. So has the university.

"It is hard to understand the logic that is said to demand that governmental research funds should be expended on the physical metallurgy of alloys because of the immediate defense needs of the Country for hardware, but that little or no money should be spent on the study of the extractive processes that make these metals available in the first place. A marked increase in research productivity in this field would, I should think, attract more students into the field. At the moment, there are fearfully few.

"If the universities were to exert the leadership they should, the emphasis would change away from thermodynamics and solution theory to other sections of physical chemistry, to inorganic chemistry, and to pertinent parts of the field of process design now in the hands of the chemical engineer; in teaching, perhaps some realignment of courses will be necessary. Some design, especially process design, must be introduced and fostered among metallurgists, else surely the chemical engineers will engulf us. . . ."

ISD LUNCHEON

Tuesday, Feb. 16th, also witnessed the Annual Luncheon and Business Meeting of the Iron and Steel Division. Michael Tenenbaum, 1959 Chair-

Robert F. Mehl delivering his *Commentary on Metallurgy*, 1960 Howe Memorial Lecture.

Charles M. White, Chairman of the Board, Republic Steel Corp., is on the receiving end of The Benjamin F. Fairless Award (above). At right, President Pyle bestows the Extractive Metallurgy Division Award on Mrs. R. C. McQuire (widow of R. C. McQuire), L. S. Renzoni, and W. V. Barker.

man of the Division, presided by first introducing T. E. Dancy, H. N. Lander, and A. T. Sadler, recipients of the Robert W. Hunt Award for 1960. The Award, for their paper *Process Analysis of Blast Furnace Operation with Oxygen and Steam*, was formally presented at The Metallurgical Society's Annual Dinner that evening.

Also introduced was Harry Holiday, Jr., recipient of the J. E. Johnson, Jr., Award "in recognition of his contribution to the production of very large tonnages in blast furnaces, achieved through the skillful use of agglomerated materials and operating practices." Formal presentation was also made that evening.

Dr. Tenenbaum then expressed the Division's gratitude to Dr. Mehl for his provocative analysis of the metallurgical profession. The Howe Memorial Award Certificate was presented at that time.

ISD activities for 1959 were next reviewed by Dr. Tenenbaum. He noted that there were more than 2660 members in the Division, thanks to a vigorous membership campaign, and that the Division was financially solvent.

Luncheon speaker was Hjalmar W. Johnson, vice president, planning and research, Inland Steel Co. His subject was *Midwestern Steelmaking*. In his talk, Mr. Johnson recalled the beginnings of steelmaking in that part of the Country, when the major part of production went toward rails for the Nation's rapidly-expanding railroads.

METALLURGICAL SOCIETY DINNER

The Winter Garden high atop the Sheraton-Atlantic Hotel was the scene of The Metallurgical Society's Annual Dinner Tuesday evening. Presiding was John Chipman, 1959 Society President. After introducing persons seated at the head table, Dr. Chipman turned the floor over to Michael Tenenbaum. Dr. Tenenbaum then presented the Robert W. Hunt Medal and J. E. Johnson, Jr. Award. Dr. Chipman himself presented the Rossiter W. Raymond Memorial Award to Paul Shewmon, assistant prof. of metallurgy, Carnegie Institute of Technology. Herbert Hollomon . . . former student under John Wulff at MIT . . . next took the podium to tell how this educator had inspired his students. This was a preface to presentation of a Special Citation to Dr. Wulff, as one who has added to the stature of the metallurgical profession.

The Dinner speaker was C. Stark Draper, head of the Department of Aeronautics and Astronautics, MIT. Speaking on *Guidance of Spacecraft*, Dr. Draper gave a short account of navigation as used in the past and present. The methods applicable for spacecraft are different, says Dr. Draper, in that they cannot rely on signals from the earth, and for the time being, cannot use human pilots. The guidance system containing gyroscopes (to furnish a "sense of direction"), accelerometer (to measure speed), and a computer (to relate position with the location of the target) promises the solution to travel in interplanetary space, he explained. The reliability of this system has been proved and is being used in the Polaris ballistic missile, he noted.

EMD LUNCHEON

At 12:15 pm Wednesday, Feb. 17th, the Annual Stag Luncheon and Business Meeting of the Extractive Metallurgy Division took place, with A. E. Lee, Jr., 1959 EMD Chairman, presiding. First order of business was an expression of thanks and presentation of a titanium plaque to H. H. Kellogg, 1958 Chairman of the EMD. Next came presentation of the Extractive Metallurgy Division Award to W. V. Barker, R. C. McQuire (posthumously), and L. S. Renzoni for their paper *Direct Electrorefining of Nickel Matte*, which appeared in the June 1958 issue of JOURNAL OF METALS. Luncheon speaker was Arthur H. Dean, lawyer and educator, who spoke on *The Impact of the Anti-trust Laws on American Business and on Our Ability to Compete with the Soviet Union*.

AIME BANQUET

Replete with tails and dinner jackets was the AIME Annual Banquet and Reception in the Grand Ballroom and the Terrace Ballroom of the Statler-Hilton Hotel on Wednesday evening. Howard C. Pyle, presiding, AIME Awards were presented, including The James Douglas Gold Medal to Augustus B. Kinzel . . . The Benjamin F. Fairless Award to

At upper left, A. T. Sadler, T. E. Dancy, and H. N. Lander receive the Robert W. Hunt Award from the Award Committee's Chairman, Michael Tenenbaum. Above, 1959 EMD Chairman A. E. Lee, Jr. confers a titanium plaque on H. H. Kellogg, the Division's 1958 Chairman. At left, A. B. Wilder, Chairman of the ISD's Acid Converter and Basic Oxygen Steel Committee, holds the first of the Committee's newly-established award. Recipient was Herbert W. Graham, retired vice president and director of technology, Jones & Laughlin Steel Corp.

Charles M. White . . . and the Alfred Nobel Prize to Paul G. Shewmon for the paper. *The Redistribution of a Second Phase during Annealing in a Temperature Gradient*, published in TRANSACTIONS, October 1958.

As one of Mr. Pyle's last acts as AIME President, he introduced Henry E. Ford of E. I. duPont de Nemours & Co., with which 1960 AIME President Joseph L. Gillson is associated. Mr. Ford explained that in lieu of presenting banquet favors or souvenirs this year, the duPont Co. felt that funds were more vitally needed for the new United Engineering Center. Speaking thus, he presented AIME with a check for $10,000.

Joseph L. Gillson, chief Geologist at du Pont, then stepped to the rostrum and took the gavel of AIME President from Howard C. Pyle.

EMD LECTURE

At 11:00 am Thursday, Feb. 18th, Charles R. Kuzell of Phelps Dodge Corp. delivered the Second Extractive Metallurgy Division Lecture. Speaking on *The Development of Modern Copper Smelting*, Mr. Kuzell traced today's practices from copper extraction's origins . . . through its renaissance . . . and up to present day practices. The industrial revolution and the introduction of electricity, coupled with the newly-developed scientific processes brought copper to pre-eminence during the 19th century, he explained. The reverberatory furnace with the bessemer converter processing the rich ore supplies of Montana and Arizona made this Country the main supplier of copper in the first half of the 20th century, he noted, tracing the industry's growth. As for the future, Mr. Kuzell sees the introduction of oxygen blowing . . . more intensive extraction of valuable byproducts by using the electric furnace . . . and the new cyclone-type furnace with preheated air.

CONVERTER LUNCHEON

The Acid Converter and Basic Oxygen Steel Committee Luncheon was also held on Thursday. Committee Chairman A. B. Wilder presided. Among honored guests introduced were Professor Bo Kalling of Sweden, who developed the Kaldo process . . . Professor Herbert Trenkler of Austria, who was influential in the development of LD steelmaking . . . and Professor Pierre Coheur of Belgium, instrumental in introducing oxygen-steam blowing to converters and the LD-AC process for treating high-phosphorus pig iron.

The first of the Committee's newly-established award for a major contribution to acid converter or basic oxygen practice was bestowed on Herbert W. Graham, retired vice president and director of tech-

nology, Jones & Laughlin Steel Corp. (For the complete story, see p. 240 of the March issue.)

Luncheon speaker was Forrest H. Kirkpatrick of Wheeling Steel Corp., who talked about management's function as applied to personnel.

Review of Technical Sessions

At the 1960 AIME Annual Meeting, the JOURNAL OF METALS asked a number of persons to act as reporters in order to provide an adequate coverage of the many simultaneous technical sessions. In past years, we have tried in vain to provide coverage by running from one session to another. We feel that our new system will provide you with better coverage. Unfortunately, it was impossible to secure reports on each and every session, and with your help we hope to remedy this situation in the future. For the following summaries, we are indebted to the indicated reporters . . . and we sincerely thank them for their assistance.

IRON AND STEEL DIVISION

Direct Reduction of Iron Ore

Reviewed by K. A. Phillips of American Zinc, Lead, & Smelting Co.

Reduction Kinetics of Magnetite in H_2-H_2O-N_2 Mixtures, by W. K. McKewan, U.S. Steel Corp.

The author gave the results of precise laboratory-scale tests using discs of sintered magnetite suspended in gaseous mixtures of hydrogen, nitrogen, and water vapor. The magnetite was first reduced to ferrous oxide and then to metallic iron having a porosity of about 50 pct. Although the transient layer of ferrous oxide is inconspicuous, its reduction appears to control the over-all reaction rate. The rate is proportional to the partial pressure of hydrogen, and is reduced by the presence of water vapor—which temporarily poisons part of the reaction sites.

Nu-Iron, a Fluidized Bed Reduction Process for Iron Ore, by T. F. Reed, J. C. Agarwal, and E. H. Shipley, U. S. Steel Corp.,

(This paper was published in the April issue, pp. 317-320, under the title, *Nu-Iron, A Fluidized-Bed Reduction Process.*)

Versatility of the R-N Process, by G. G. Reed, Jr. and R. P. Smith, National Lead Co.

A great variety of iron ores has been treated successfully in the large pilot plant at Birmingham, Ala. The process is very flexible; low-grade ores can be beneficiated either before or after treatment, and many kinds of solid carbon fuels can be used.

Ores coarser than 1 in. are crushed to that size before treatment; material finer than 20 mesh should usually be agglomerated. A mixture of the ore and fuel is then passed through a rotary kiln fired with gas or oil. Carefully-controlled additions of air are made at several points along the kiln. The temperature must be high enough to achieve reduction, but low enough to avoid the fusion of the charge. In this way no rings have formed during five years of operation, and no lining has been replaced because of chemical attack.

The product contains 95 pct of its iron in the metallic form, and it is briquetted cold without the use of binders. Few impurities are retained. Volatile metals, like lead and zinc, are rejected as fume with the exit gases. A reasonable content of sulfur can be reduced to 0.05 pct in the product. Manganese, chromium, vanadium, and titanium tend to stay in the non-magnetic tailings. Phosphorus charged in the form of calcium phosphate also enters the tailings, but phosphorus fed to the kiln as ferrous phosphate tends to report with the iron product.

Above, 1959 ISD Chairman, Michael Tenenbaum presents the Division's 1960 J. E. Johnson, Jr. Award to Harry Holiday, Jr., superintendent of blast furnaces, Armco Steel Corp.

At right, Charles R. Kuzell delivers the Second Extractive Metallurgy Division Lecture on *The Development of Modern Copper Smelting.*

Phosphorus in the Direct Reduction of Iron Ores, by K. L. Komarek, New York University.

This paper provides a sound theoretical explanation why 99 pct of the phosphorus in one iron ore fed to an R-N kiln is eliminated in the tailing and why 70 pct of the phosphorus remains in the iron product made from another ore. Calcium phosphate does not yield its phosphorus to the iron compounds produced in the kiln, whereas ferrous phosphate is reduced to iron phosphide, which tends to report with the iron product. The addition of fine lime to an ore containing ferrous phosphate is only partly effective in breaking down the latter compound, and undesired side reactions are apt to economically offset the modest gain in phosphorus elimination.

Fundamental Studies

Reviewed by J. C. Fulton of Allegheny Ludlum Steel Corp.

Activity of Tin in Iron-Tin-Carbon Alloys, by R. Shields and T. B. King, Massachusetts Institute of Technology.

Using the equilibrium distribution method, the activity of tin was measured in the molten iron-tin alloys in the range 0 to 4.4 wt pct tin and in iron-carbon melts containing up to 10 wt pct tin. This study utilized both silver and bismuth as the phase immiscible with iron; the activity of tin is known in these metals from previous experimental studies.

At 1550°C the tin activity in the iron-tin binary shows moderate positive deviations from the ideal. The effect of carbon at this temperature is to increase the tin activity, the interaction becoming more pronounced as the carbon content approaches saturation. An increase of the tin activity at lower temperature, determined in carbon-containing melts, indicates a positive heat of mixing of tin in the iron-carbon-tin system. The results are presented herein by expressing the logarithm of the tin activity coefficient as a linear function of the

atom parameter, E^{a}_{sn}, at 1550°C at infinite dilution of carbon is tentatively + 1.4 The interaction parameters at 1550°C and 1275° representing the effect of tin on carbon at saturation are, respectively, + 2.6 and + 3.5. The values of the carbon solubility extrapolated to zero pct in tin at both temperatures agree well with the accepted values.

Effects of Basicity on Water Solubility in Silicate Melts, by J. M. Uys, Allegheny Ludlum Steel Corp. and T. B. King, MIT.

The authors' experimental results indicate that basicity has little effect on water solubility in acid compositions; when approaching basic compositions the water solubility increased for cations with a small attraction for oxygen ions and decreased for cations with a stronger attraction for oxygen ions. Temperature had little influence on water solubility for those melts studied. It was also found that the melt water content varied as the square root of the water partial pressure. The experimental results were discussed on the basis of two reactions: one in which the water molecule reacted with doubly-bonded oxygens and one in which the water molecule dissolved due to interaction with oxygen ions in the melt.

Solubility of Oxygen in Delta Iron, by E. S. Tankins and N. A. Gokcen, University of Pennsylvania.

E. S. Tankins and N. A. Gokcen presented some new results on the solubility of oxygen in delta iron. Zone-refined iron was equilibrated with various gas mixtures of H_2O and H_2 in the temperature range of 1410° to 1510°C. Their data can be represented by the equation $\log \% O = -\frac{12{,}660}{T} + 5.51$. Extrapolation to 850°C indicates a solubility of only 1 ppm (0.0001 pct) in alpha iron. This is much lower than existing values.

Thermodynamic properties of sulfur in pure liquid iron, cobalt, and nickel were presented by M. R. Baren and N. A. Gokcen. The equilibrium in the reaction of H_2 with dissolved sulfur in pure cobalt and nickel was investigated and correlated with existing data for iron. Results show that the equilibrium constant $K = \frac{H_2S}{H_2}\frac{1}{\%S}$ is 2.5 times smaller for nickel than for iron, whereas K for cobalt and iron is approximately the same. The K for nickel decreases slightly with increasing temperature, while K for iron and cobalt increases with increasing temperature.

Iron and Steelmaking

A Staff Review

Production of Iron from a Silicious Ore by a Two-Step Electric Smelting Process, by G. E. Viens, R. A. Campbell, G. V. Sirianni, G. N. Banks, and R. R. Rogers, Canadian Department of Mines and Technical Survey.

The authors described their investigations—presently in progress—to utilize the large siliceous iron deposit in Ontario. Since mineral dressing seemed to be impractical, a two-stage smelting process in a cylindrical electric furnace was developed. In the first stage they smelted the ore with a carbonaceous reductant (coal or bark); the resultant high-silicon iron was then reacted with direct smelting ore in the second stage to yield the desired low-silicon iron. According to the authors, this process offers the following advantages: savings in lime, efficient iron recovery, and good sulfur and phosphorus control of the end product.

Purification of Steelmaking Fumes, by L. Septier and P. Leroy, Institut de Recherches de la Siderurgie Francaise.

This paper will be published in the July issue of the JOURNAL OF METALS.

Effect of Oxygen Input on Open-Hearth Steelmaking, by A. L. Hodge and C. S. Arnold, Linde Co., div. of Union Carbide Corp.

This paper was published on pp. 325-330 of the April issue of the JOURNAL OF METALS.

(Reports on EMD and IMD sessions will be published in the June and July issues.)

AIME STAFF:
SECRETARY—ERNEST KIRKENDALL
ASST. SECRETARIES—J. B. ALFORD, H. N. APPLETON, J. C. FOX, R. W. SHEARMAN
ASST. TREASURER—JOHN LYNCH
METALLURGICAL SOCIETY STAFF:
SECRETARY—R. W. SHEARMAN
ASST. SECRETARY—D. C. JOHNSTON

NEWS OF YOUR PROFESSION

May 26-27 Are Dates of 14th New England Regional Conference

Metalworking Tomorrow is the theme of the 14th New England Regional Conference, meeting May 26-27 in the Bay State Room of the Hotel Statler-Hilton, Boston. The Conference is being sponsored by the Connecticut, Hudson-Mohawk, and Boston sections of AIME.

Thursday, May 26th, will feature two sessions: High Energy Rate Forming and Special Metalworking Processes. A total of seven papers and two panel discussions will make-up the day. Friday morning, May 27th, will be devoted to a session on Extrusion. That afternoon will see a plant visit to the Avco Research and Advanced Development Center of Avco Corp. in Wilmington, Mass.

Registration, including the cost of a May 26th luncheon and social hour, is $10 for AIME members; $15 for non-members. Advance registration may be made by sending a check to *F. S. Chudy, Olin Mathieson Chemical Corp., New Haven, Conn.* Registrants should make their own hotel registrations.

French Metallurgical Society Meeting Oct. 17

The fall meeting of the Société Francaise de Métallurgie will be held in Paris Oct. 17-21. Heat treatment of metals is the theme of the meeting, and the following topics will be discussed: physical and chemical transformations due to heat treatments and their consequences . . . problems concerning the heat treatment of parts made of special steel . . . application of heat treatment to new ferrous and nonferrous alloys . . . and heat treatment of large castings and forgings.

For information on registration and other details as they become available, write: *Secretary, Société Francaise de Métallurgie, 25, Rue de Clichy, Paris (9e).*

Fall Meeting Abstracts

June 29th is the deadline for submission of abstracts to be considered for presentation in IMD-sponsored sessions at the 1960 Fall Meeting of The Metallurgical Society.

In order to be considered for inclusion in the program, each submission must include:

1) A 200-300 word abstract typed double-space on one side of the paper only. (No photographs, figures, tables, or diagrams, please.)

2) Complete mailing address of *each* author on a separate sheet, together with title of paper being submitted.

3) Acknowledgements of research sponsorship, *where applicable.*

All required information and abstracts should be submitted in 3 copies to:
The Metallurgical Society of AIME, IMD Program Committee, 29 W. 39th St., New York 18, N. Y.

Refractory Metals and Alloys Symposium May 25-26 in Detroit

The Refractory Metals and Alloys symposium sponsored by the Institute of Metals Division and the Detroit section, AIME, is coming up May 25-26. Headquarters for the symposium will be the McGregor Center on the Wayne State University campus in Detroit.

A total of four sessions and 16 papers will comprise the meeting. One session will be on the General Metallurgy of refractory metals and alloys, while two will be devoted to the title Refractory Metals and Alloys itself. A fourth will be on General Engineering of such materials.

The program for the meeting appeared on p. 344 of the April issue.

ASTM Schedules Two Materials Symposia for Meeting June 26-July 1

Two symposia on materials science will be included in this year's Annual Meeting of the American Society of Testing Materials, to be held at Chalfonte-Haddon Hall in Atlantic City, N. J., June 26-July 1. Progress in Materials Sciences, and Nature and Origin of Strength of Materials incorporate a total of nine papers. Progress in Materials Sciences will convene at 9:30 a.m., Monday, June 27. Papers scheduled are: *Accomplishments and Limitations of Solid-State Theory,* by Harvey Brooks, Harvard University . . . *Contributions of Surface Chemistry and Physics,* by M. J. Sinnot, University of Michigan . . . *Relationship Between Mechanical and Electrical Properties of Semiconductors,* by J. N. Hobstetter, University of Pennsylvania . . . and *Ductile Ceramics,* by E. R. Parker, U. of Calif.

The afternoon session includes the following papers:

Dislocation Motions and the Yield Strengths of Solids, by J. J. Gilman, General Electric Co. . . . *Fatigue Strength of Solids,* by G. M. Sinclair, University of Illinois . . . *Resistance to Creep Deformation and Fracture in Metals Alloys,* by Frank Garofalo, U.S. Steel Corp. . . . *Brittle Fracture and the Strength of Metals,* by E. T. Wessel, Westinghouse Electric Corp. . . . and *Size and Shape Effects on Fracture of Solids,* by George Irwin, Naval Research Laboratories.

NOTICE

In answer to inquiries about directory cards for The Metallurgical Society Directory, it should be noted that there will be no such Directory published this year. By decision of The Metallurgical Society's Board of Directors, its Directory is published every two years, the latest one included in the July 1959 issue of JOURNAL OF METALS. Thus, the next Directory will appear in July 1961.

AIME

BOARD OF DIRECTORS

Recent actions taken by the Institute Board of Directors.

► A new grade of Institute membership has been proposed. W. R. Hibbard, Jr., has suggested that a grade of Fellow be authorized to recognize leadership and outstanding contributions to the profession. Dr. Hibbard stressed that the designation be made by people in the metallurgical profession as a whole rather than at Institute level.

J. H. Hollomon moved that the Board of Directors endorse, in principle, the proposal of the Committee on the Metallurgical Profession that a grade of Fellow be established and that this Committee be instructed to bring a final proposal to that effect to a future Board meeting. The proposal is to incorporate the following points: 1) Selection be based on the broad range of metallurgists; 2) Nominations for the grade of Fellow be made by a Standing Committee of The Metallurgical Society, and that this Standing Committee include both "Fellows" and "non-fellows"; and 3) That the rules incorporate the principle that members or groups of members can propose the names of individuals for the grade of Fellow.

► John Chipman, Past-President of The Metallurgical Society, has reported that the Ferrous Metallurgy Committee of the Institute of Metals Division is planning a Symposium on Austenite Decomposition during the Fall Meeting at Philadelphia Oct. 17-21. The Committee plans to invite three prominent engineers from abroad to participate.

► A move to begin designating the Annual Meetings of AIME by number was begun at the latest Meeting in February. Secretary Ernest Kirkendall is looking into the matter.

► Lloyd E. Elkins, President-Elect of the Institute in 1961, is the new Chairman of the AIME's New Building Membership Fund Raising Campaign. The Society of Petroleum Engineers member succeeds Joseph L. Gillson, who resigned upon taking over the reins of AIME President.

► Leo A. Rogers of the University of Utah was named winner of the 1959 Student Prize Paper sponsored by the Undergraduate Division of The Metallurgical Society. Title of his paper was *Spectrophotometric Analysis of Niobium.*

Announce Society Committee Appointees

Appointments to Committees of The Metallurgical Society during President Carleton C. Long's term of office have been announced. They are as follows:

Admissions: W. L. Brytczuk, Chairman; S. C. Carapella, Jr., J. W. Hanley, T. D. Jones, H. C. Larson, Harold Margolin, and Shadburn Marshall.

Education: M. E. Nicholson, Chairman; C. T. Evans, Jr., W. R. Hibbard, Jr., A. R. Lytle, H. W. Paxton, Paul Queneau, T. A. Read, R. G. Redelfs, G. R. St. Pierre, and M. E. Wadsworth.

Finance: A. W. Thornton, Chairman; T. D. Jones, and A. R. Lytle.

Robert Lansing Hardy Gold Medal: C. L. McCabe, Chairman; R. L. Smith, Michael Tenenbaum, and Norman Weiss.

Membership: J. H. Keeler, Chairman; J. J. Golden, T. A. Read, and R. J. Stevens.

Committee on Metallurgical Profession: W. R. Hibbard, Jr., Chairman; Morris Cohen, R. C. Cole, C. T. Evans, Jr., C. L. McCabe, E. R. Morgan, J. P. Nielsen, B. R. Queneau, R. J. Raudebaugh, G. A. Roberts, A W. Schlecten, and David Swan.

Nominating: W. A. Dean, Chairman; Morris Cohen, B. W. Gonser, N. J. Grant, J. S. Marsh, C. T. Marshall, O. T. Marzke, J. H. Schloen, and P. T. Stroup.

Programs: J. H. Jackson, Chairman; H. B. Emerick, W. J. Harris, Jr., M. A. Steinberg, W. W. Stephens, David Swan, and C. R. Taylor.

Publications: D. J. Carney, Chairman; Robert Maddin, J. H. Hollomon, H. H. Kellogg, T. B. King, F. C. Langenberg, D. L. McBride, W. O. Philbrook, R. L. Smith, J. D. Sullivan, F. L. Vogel, J. H. Jackson (ex officio), and J. S. Smart, Jr. (ex officio).

Special Committees

Engineering Management: J. C Kinnear, Jr., Chairman; J. D. Hanawalt, Rush Lincoln, Bruce Old, Merritt Williamson, and H. K. Work.

Metals Research Publications Fund: A. R. Lytle, Chairman; T. K. Graham, and David Swan.

Committee on Fiscal Policy and Future Developments: David Swan, Chairman; H. B. Emerick, T. D. Jones, C. C. Long, A. R. Lytle, O. T. Marzke, J. S. Smart, Jr., and A. W. Thornton.

PERSONALS

(Continued from page 372)

Corp., will share the savings he helped create under a recently issued patent. Used at the Hayden, Ariz., sponge iron plant of Kennecott Copper, the invention will provide new, automatic cycling which permits a periodic discharge of fully-cooled sponge from the cooler during rotation without the entry of air.

The US patent is the first granted the Corp. as a result of its patent plan program; therefore, Mr. Franz will share a $1000 award, plus 25 pct of the savings the invention permits over a 12-month period.

R. W. Guard is now manager of Product and Process Development Engineering in the Diamond Products section, Metallurgical Products dept., General Electric Co. Dr. Guard was formerly with the General Electric Research Laboratory, where he worked on high temperature alloys development in the Alloys Studies section.

James S. Vanick has retired as a research metallurgist with The International Nickel Co. Inc. Mr. Vanick became associated with International Nickel in 1922, and his primary interests have been in iron foundry products and nonferrous alloys. An active AIME member, Mr. Vanick is a past Director of the Institute.

L. W. Krum has been appointed Asst. Sales Manager of the Eastern div., Chromium Mining and Smelting Corp. Prior to joining the Corp., he was general manager at Strong Steel Foundry Co., Buffalo, N. Y. He will now be located in the Philadelphia area.

F. J. Shortsleeve, E. J. Boyle, and **Edward Epremian** are among recent promotions announced by the Union Carbide Metals Co., div. of Union Carbide Corp. All appointments are in the Co.'s Technology dept.

Dr. Shortsleeve has been appointed director of research for the dept. M. Boyle goes from executive engineer to director of development in the dept. Dr. Epremian advances from senior research metallurgist to technical co-ordinator in New York.

Richard A. Flinn, professor of metallurgical engineering, University of Michigan, has been retained as a consultant by the Non-Ferrous Founders' Society. Dr. Flinn, in charge of the Cast Metals Laboratory at Michigan, will help translate foundry science and technology into operating practices.

James F. Schumar has left his post as associate director of the Metallurgy div., Argonne National Laboratory, in order to join the General Atomic div., General Dynamics.

STUDENT NEWS

Missouri School of Mines

The Missouri School of Mines and Metallurgy student chapter is the 1959 winner of the AIME Student Chapter Contest. Based on an increase of 87 members during the year—77 pct over 1958—the chapter won a $100 cash award.

The five chapters submitting the next highest number of student applications during 1959 each received a banner of recognition. They are: University of Texas (82); Louisiana State University (53); University of Minnesota (45); Texas Technological College (44); and Texas College of Arts and Industry (42).

Other increases in schools with AIME metallurgy chapters include:

School	Gain	Pct Increase
Univ. of Alabama	6	54
Univ. of Arizona	44	45
Univ. of California	20	65
Carnegie Institute	29	223
Case Institute	6	40
Colo. School of Mines	35	39
Cornell University	7	78
Univ. of Illinois	22	110
Ill. Inst. of Tech.	6	60
Univ. of Kansas	13	65
Univ. of Kentucky	2	22
Lafayette College	2	67
Lehigh University	12	133
Mass. Inst. of Tech.	20	40
Mich. Col. of M & T	38	64
Univ. of Michigan	32	800
Univ. of Minnesota	45	500
Mont. School of Mines	35	84
Univ. of Nevada	8	44
N.M. Inst. of M & T	25	78
New York Univ.	9	50
Ohio State Univ.	2	20
Univ. of Oklahoma	32	35
Univ. of Penn.	7	67
Penn. State Univ.	19	31
Univ. of Pittsburgh	13	43
Poly. Inst. of Bkyln.	8	100
S. Dak. Sch. of Mines	16	44
Stanford University	19	211
Univ. of Utah	22	169
Univ. of Washington	5	50
Wash. State Col.	2	25
Wayne University	5	45
Univ. of Wisc.	25	76
Yale University	2	50

Pennsylvania State Univ.

The Mining Society of Pennsylvania State University held its Annual Career Forum in the campus' Mineral Industries Auditorium on March 16th. Representing the different industries were: Herbert Z. Stuart, manager of exploration, Phelps Dodge Corp. (metallic industry) . . . H. A. Corre, supt. of Warner Co, Bellefonte, Pa. (nonmetallic industry) . . . Jesse F. Core, vice president of coal operations for U.S. Steel Corp. (coal industry) . . . J. C. Cosgrove, district manager of the Goodman Manufacturing Co. (sales) . . . and Donald W. Mitchell, chief of the mine experiment section for the US Bureau of Mines.

Case Institute of Technology

Case Metallurgical Society's March 8th meeting was exclusively geared to careers in metallurgy. Four senior metallurgists with demonstrated knowledge in the subject discussed *Job Interviewing*. Topics covered included: 1) type of pre-interview preparation; 2) kinds of approaches used by interviewers; and 3) poise in an interview.

Washington State University

On Feb. 9th students of AIME on the Washington State campus toured the Trentwood works of Kaiser Aluminum Corp. at Spokane. Then on March 29th a group of 30 heard Perry L. Weston, Jr., of Pacific Northwest Alloys, speak on the making of ferro alloys. Dr. Weston is director of research at the company.

NEW STUDENT MEMBERS

Polytechnic Inst. of Brooklyn
Aliotta, Joseph
Beris, Norman H.
Guenther, Reinhold W.
Kellman, Arnold R.
Kimler, George W.
Larsen, Donald P.
McNicholas, Thomas M.
Schecter, Edward
Schwartz, Milton S.

Columbia University
Ericksen, Richard H.
Maiya, Subraya P.

Drexel Institute of Technology
Godshall, John L.

Iowa State University
Kontrimas, Richard

Lehigh University
Houston, James H., Jr.

University of Michigan
Grinnell, Vernon E., Jr.
Morse, Robert V.
Sigsbee, Raymond A.
Sundberg, David V.

University of Minnesota
Gerstein, Stanley R.

City College of New York
Kudlac, John J.
Rosenfeld, Joshua H.

Pennsylvania State University
Benford, James G.
Mumau, George R.

Rensselaer Polytechnic Institute
Marciano, Michael A.
Ranish, Barry E.

Stevens Institute of Technology
Lacquement, Hubert W.

Stanford University
Robbins, Jack L.

University of Washington
Bolstad, Donald A.
Dahlgren, Shelley D.

University of Wisconsin
Allen, Robert E.

The $100 check, received by A. W. Schlechten at the Annual Meeting on behalf of the Student Chapter of AIME at the Missouri School of Mines and Metallurgy, is handed over to the winners (above). The money will be prorated among the Chapter's three sections according to the number of applications obtained by each group. Pictured are (left to right) Robert Piekarz, Chairman of the Mining section; Prof. C. R. Christiansen, Mining section advisor; Dr. G. C. Amstutz, Chapter advisor; Dr. Schlechten; Carl Vansant, President of the Student Chapter; Terry Mills, Chairman of the Metallurgy section; and William F. O'Neal, Chairman of the Petroleum section.

AROUND THE SECTIONS

The **Philippines** section, AIME, listened to the Country's Director of Mines, Benjamin M. Gozon, during one of its recent meetings. Mr. Gozon's subject was: *A Review of the Philippine Steel-Nickel Project.* The geographical boundaries of this project include the Country's islands of Nonoc, Awasan, Hanigad, and Southern Dinagat. Geographical exploration of this area estimates its reserve as 157 million tons of ore containing 1 pct Ni, 46.7 pct Fe, and 0.8 pct Co.

Investigations of these reserves were conducted by the Philippine government and Japanese mining firms prior to World War II, explained Mr. Gozon. However, no economic metallurgical process was developed for their exploitation.

"Favorable market trends, coupled with acute shortage of nickel in the world market in 1953 and accentuated by the successful exploitation of similar resources in Cuba and New Caledonia for nickel production (see the March issue of JOURNAL OF METALS), aroused local interest in the investigation of Surigao laterite." (Surigao is on the northern tip of Mindanao.)

The US Bureau of Mines in 1954 demonstrated that ferronickel could be produced from the ores by an electric smelting process using bagasse (the residue of sugar cane) and coke as reductant. It was 1956 before the US Bureau of Mines, participating with the Philippine Bureau, carried out pilot tests, seeking information on the design, building, and operation of an electric smelting plant for the extraction of ferronickel. They worked with 300 tons of Surigao ores. The Philippine Bureau director explained: "Results of tests not only indicate the successful economic recovery of nickel and cobalt, but also the feasibility of producing mild steel from the high iron slag by a direct reduction technique using electricity for power and low-grade coal, wood chips, or bagasse for reductant."

Major advantages of the process are:

1) The reductant material is unlimited; any carbon-bearing material may be used.

2) Fluxless smelting for ferronickel and crude steel is successfully established; this eliminates use of limestone.

3) Controlled carbothermic reduction applied on the high-iron slag will produce steel directly, thus eliminating the pig iron stage.

4) Integration of preparation techniques prior to smelting will reduce substantially thermal and electrode requirements, improve metallic recoveries, and reduce the number and sizes of smelting units.

"It appears that a 200-tpd plant is the economic minimum," said Mr. Gozon, "while its economic optimum is estimated at 5000-6000 tpd.

"Ferronickel smelting has been proved successful by independent tests carried out by Strategic Udy Processes Inc. of the US and Takaduwa of Japan and confirmed by commercial operation in New Caledonia (see p. 202 of the March issue). Crude or semi-steel production by controlled reduction is likewise confirmed by similar independent tests by Strategic Udy Prossesses Inc. and Takaduwa in pilot-scale operations. The separation and processing of nickel and cobalt from ferronickel employing an adaptation of Ralston-Udy process parallels the scheme practiced by International Nickel Corp. at its Port Colborne (Canada) plant."

The Philippine director went on to tell his AIME-member audience, "You are all aware that Celebes (island in Indonesia), New Guinea, and Cuba have similar vast deposits of laterite. It has been announced that a Dutch-American combine will soon exploit the laterite deposit of Dutch New Guinea. Japan has also been reported to have sent a party to Celebes to make investigation of its laterite deposit. New Caledonia has nickeliferous deposits being worked out by Le Nickel of France.

"In the light of these facts, we, in the Bureau of Mines, believe that the time to develop and operate our laterite deposits in Surigao is now, if the project is to succeed."

Maricopa, newly-organized subsection of the Arizona section, heard P.D.I. Honeyman, president of Inspiration Consolidated Copper Co., speak on the *History and Future of Inspiration, the International Smelter, and the Christmas Mine,* at a meeting March 3rd. A total of 63 persons attended the meeting in the Westward Ho Hotel, Phoenix. Then, on April 7th Mr. Kenneth L. Tatman, chief metallurgist and mill supt. of Idorado Mining Co., addressed the group on his company's operations in Telluride, Colo. This meeting was also held at the Westward Ho Hotel.

The subsection has scheduled regular dinner-meetings for the first Thursday of every month except June, July, August, and September.

The Mineral Industry Group of **Pittsburgh** section was introduced to the *Use of Natural Gas in the Experimental Blast Furnace* during its March 15th meeting. Edward J. Ostrowski, project leader, Experimental Blast Furnace Operation, US Bureau of Mines, Pittsburgh, addressed the Gateway Plaza Restaurant gathering.

After describing the experimental work at Bruceton, Pa., Mr. Ostrowski concluded that natural gas injection through the tuyeres can be used effectively with: higher blast temperatures, lower coke rates, and reduction of sulfur content of the pig iron.

Washington, D.C. section heard a discussion of *The Need for Sound Engineering Judgment in the Minerals Industries* when Felix Wormser, vice president of the St. Joseph Lead Co., addressed the March 1st meeting. Mr. Wormser was formerly the assistant secretary for Mineral Resources in the US Dept. of the Interior.

US Strategy and National Stockpile Programs were discussed at its April 5th meeting. Speaking was John D. Morgan, Jr., consulting engineering, who took up the subject previously at the Council of Economics session during the AIME Annual Meeting.

Chicago section played host to 56 members and guests during its March 2nd dinner-meeting at the Chicago Bar Association. Speaker of the evening was N. H. Polakowski, professor of metallurgical engineering at Illinois Institute of Technology. Dr. Polakowski spoke on *New Progress in Old Metal Forming Techniques.* Technical chairman for the meeting was Nelson George, chief metallurgist, Gary Sheet & Tin Mill, U.S. Steel Corp.

The section's 1960 Executive Committee includes Carl H. Samans, Chairman; Melvin E. Nickel, Secretary-Treasurer; J. P. Weir, Asst. Secretary-Treasurer; E. C. Rudolphy, Program Chairman; and Kurt Mattson, Membership Chairman.

St. Louis section toured the University of Illinois' Dept. of Mining and Metallurgical Engineering during its April 8th meeting. Following the afternoon-long tour, a dinner-meeting featured a talk on *Minerals, A Key to Soviet Power.* Demitri Shimkin delivered the authoritative talk.

Western section, NOHC, on March 16th was host to J. B. Schlossgerg, Chairman of the Institute of Scrap Iron and Steel Committee on

Technology and Maintenance. He spoke on scrap preparation, while also alluding to new developments in this field.

Connecticut section's March 9th meeting speaker was C. E. Larson, associate manager of research, Union Carbide Corp. The title of Dr. Larson's talk was *Materials Research in Private Industry*. This was the third in the Section's series on materials research. Dr. Larson noted the fruits of basic research, such as purified forms of uranium and zirconium. He also pointed to the solid-state physics approach to materials problems.

Scene of the dinner-meeting was the Colonial House in Hamden.

Southern California section's May 12th meeting will feature a talk by Pol Duwez of California Institute of Technology. Dr. Duwez will speak on *Micro-Metallurgy in Micro-Seconds*. Born in Mons, Belgium, Dr. Duwez served as a member of the Science Advisory Board to the Chief of Staff, USAF, from 1945 to 1955. He has been a professor at Cal Tech since 1952.

San Francisco section's March 12th meeting was a social affair. It marked the annual dinner-dance with the Section's Woman's Auxiliary. Scene of the event was the Mark Hopkins Hotel.

Utah section had as its guest speaker March 16th C. J. Lewis, manager of the Chemical div., Colorado School of Mines Research Foundation. Dr. Lewis addressed the dinner-meeting on *Chemical Approaches to the Winning of Metals*.

El Paso section's March 9th meeting featured a discussion of *The Future of El Paso With Respect to Water*. Speaker of the evening was Carroll C. Cason of the City's Public Service Board. On May 14th the Section will hold its annual Spring Dinner-Dance at the del Norte Hotel in El Paso.

Ohio Valley section has elected its officers for the 1960-1961 meeting year. They include G. H. Schippereit, Chairman; H. B. Goodwin, Vice Chairman; V. D. Barth, Secretary-Treasurer; V. W. Ellzey, Asst. Secretary-Treasurer; and R. L. Frantz, Membership Chairman.

At the Section's April 14th meeting, H. A. Bolz, Dean of the College of Engineering, The Ohio State University, spoke on *Designing Tomorrow's Engineer*. The dinner-meeting was also billed as Students' Night, and four students from Ohio State gave their impression of the University's earth sciences curriculum.

Foreign Representatives To Be at Philadelphia Castings Congress

Albert De Sy, professor of metallurgy at the University of Ghent (Belgium), is one of the many distinguished foreign speakers scheduled to address the American Foundrymen's Society Castings Congress & Exposition, taking place at Philadelphia's Convention Hall May 9-13.

Representatives from Russia, England, Australia, and Germany will also be on hand. Altogether, 217 speakers and panelists will take part in 58 sessions making up the technical program.

Metallurgists Who Read Russian Sought By *Chemical Abstracts*

Chemical Abstracts is actively soliciting the services of metallurgists who can read Russian—Ukrainian, Azerbaijani, and Georgian dialects in particular.

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The rewards of such work? To quote from *Chemical & Engineering News*: "Abstracts are permanent contributions to progress in chemistry. Abstracting develops prompt, effective reading of new chemical research results. Abstractors learn more novel chemistry and gain research ideas. Some appreciate the experience in writing clear, concise English. Ability with foreign languages increases. Also, there is an honorarium of $10 per printed page of abstracts."

Abstractors in other languages are also needed, as attested by the fact that the abstracting service reviews 8000 periodicals in 52 languages.

For more information, write: *Charles L. Bernier, Chemical Abstracts Service, The Ohio State University, Columbus 10, Ohio.*

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For interview, contact:

Ray S. Richards, Chief Metallurgist
Owens-Illinois Technical Center
1700 N. Westwood
Toledo 7, Ohio

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MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME membership on March 31, 1960, was 33,949; in addition 2,663 Student Members were enrolled.

ADMISSIONS COMMITTEE

L. L. Seigle, Chairman; W. L. Brytczuk; F. B. Foley; T. D. Jones; Harold Margolin; Shadburn Marshall.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

Alexandrovsky, George, Yonkers, N. Y.
Allen, Everett B., Toronto, Ont., Canada
Barnes, Harry H., New York, N. Y.
Bilbrey, Joseph J., Jr., Washington, D. C.
Bomberger, Howard B., Jr., E. Liverpool, Ohio
Boyle, James W., Metuchen, N. J.
Burman, Russell W., Detroit, Mich.
Clark, C. Burton, Falconer, N. Y.
Dierker, Richard C., Lorain, Ohio
Faust, John W., Jr., Pittsburgh, Pa.
Francis, Dwight A., Hales Corners, Wisc.
Freedman, Norman S., Harrison, N. J.
Garofalo, Frank, Monroeville, Pa.
Haas, Herbert H., Trenton, N. J.
Harris, Ralph W., Hanlin Station, Pa.
Houston, John V., Rolling Hills, Calif.
Huvos, Joseph B., Perth Amboy, N. J.
Johnston, Louis K., Pittsburgh, Pa.
Kondo, Yoshio, Kyoto, Japan
Kronberg, Marritt L., Schenectady, N. Y.
Morrow, Paul R., Homestead, Pa.
Myiting, Lauritz E., Wynnewood, Pa.
Ross, Arthur H., Collinsville, Ill.
Rutter, John W., Schenectady, N. Y.
St. Germain, Frank, Carmichael, Calif.
Sevier, Cameron, King of Prussia, Pa.
Sweet, John W., Seattle, Wash.
Tarnay, Helen, New York, N. Y.
Teasel, William A., Detroit, Mich.
Tennant, Charles B., Palmerton, Pa.
Viens, George E., Ottawa, Ont., Canada
Watkins, Daniel E., N. Birmingham, Ala.
Wilkinson, Donald H., Palmerton, Pa.
Woodbridge, James O., Irvine, Pa.
Zamora, Raul M., Avenida Juarez, Mexico

Associate Members

Bregar, George W., Cleveland, Ohio
Jallo, Tejan A., Haileybury, Ont., Canada
Koump, Valentin, Monroeville, Pa.
Mager, Thomas R., Murrysville, Pa.
Morrow, Bruce C., Dearborn, Mich.
Robertson, Bob M., Mexico, Mo.
Woff, Theodore F., New York, N. Y.

Junior Members

Ainslie, Norman G., Schenectady, N. Y.
Carnes, James H., El Paso, Tex.
Cline, Richard S., Monroeville, Pa.
Colandrea, Thomas R., E. Hartford, Conn.
Cortes Font de Rubinat, Pau, Mexico D.F., Mexico
Hauptman, Marvin H., Long Island, N. Y.
Herrnstein, William H., III, Newport News, Pa.
Kariawigena, Wijono, Lexington, Ky.
Kraus, Peter S., Brooklyn, N. Y.
Laidler, James J., Richland, Wash.
Latimer, Wilbur S., Malden, Mo.
Matt, Robert E., Sacramento, Calif.
May, Bobby L., Moab, Utah
McPhillips, John J., Youngstown, Ohio
Menk, James H., Mountainside, N. J.
Meyer, Harry W., Pittsburgh, Pa.
Nylen, Ronald J., Chicago, Ill.
Patterson, William R., Midland, Pa.
Platt, Alan, Annandale, N. J.
Roberts, Richard W., E. Chicago, Ind.
Sack, Bennett, New Kensington, Pa.
Scarano, Dominic J., Middletown, N. Y.
Schaffer, Philip S., Watertown, Mass.
Sheets, Allen R., Manchester, Conn.
Shiloff, Jerome C., Wilmington, Del.
Smith, Hayne M., Waterbury, Conn.
Strathdee, Barry A., Hamilton, Ont., Canada
Swartz, Paul S., Schenectady, N. Y.
Wyczalek, Edward R., Nixon, N. J.

REINSTATEMENT—MEMBERS

Fabel, Donald C., Cleveland, Ohio
Monson, Walter T., Carteret, N. J.
Nielsen, Walter N., Birmingham, Ala.
Printz, Leon J., Detroit, Mich.

REINSTATEMENT—JUNIOR MEMBERS

Gullotti, Damian B., Jackson Heights, N. Y.
Steinbrenner, Walter L., Pittsburgh, Pa.

REINSTATEMENT—CHANGE OF STATUS

Junior to Member

Cueto, Eloy M., E. St. Louis, Ill.
Kittel, J. Howard, Lemont, Ill.
Prout, Robert J., Torrance, Calif.
Silliman, Horace F., Waterbury, Conn.
Zouraeff, Peter, Richmond, Va.

Associate to Member

Frommer, Donald W., Minneapolis, Minn.
Melhorn, Wilton F., Louisville, Ky.

Student to Member

Barut, Cihat M., Stamford, Conn.
Block, Alan J., Detroit, Mich.
Brown, Lester C., Kearney, Ariz.
Raymer, David L., Latrobe, Pa.

Student to Junior

French, Ronald L., Rockford, Ill.
Potter, Vernon C., Oak Harbor, Ohio
Rubin, Alan L., Manchester, Conn.

Junior to Member

Kendall, Ernest G., Canoga Park, Calif.
Lowe, Arthur L., Jr., Lynchburg, Va.
Port, John H., Waterbury, Conn.

Associate to Member

Matricardi, Louis R., Tonawanda, N. Y.

Junior to Associate

Yake, William H., Connerxville, Tex.

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ISI Translations Listed

The following English translations are among those recently issued by the British Iron & Steel Federation and The Iron and Steel Institute. They may be obtained by addressing the British Iron & Steel Industry Translation Service, c/o The Iron and Steel Institute, 4 Grosvenor Gardens, London, S.W.1:

The Dectection of Defects, by Ultrasonic Testing, by H. Krainer and E. Krainer, *Schweisstechnik*, March 1958.

Measuring and Control Plant at the Experimental Converter of Phoenix Rheinrohr at Duisburg Ruhrort, by K. Ewe, *Regelungstechnik*, July 1959.

The Use of Electron Microscopy for the Study of Kinetic Phenomena in Previously Selected Areas, by M. Molcik and M. Klesnil, *Hutnicke Listy*, 1959.

Comparative Investigation of Defects in Heavy Forgings, by Means of Ultrasonic Waves and the Betatron, by L. Brand, *Stahl und Eisen*, January 1959.

Experience with a 15-MeV-Betatron Used for the Nondestructive Testing of Steel Products, by H. Krächter, *Stahl und Eisen*, April 1959.

Continuous Ultrasonic Testing of the Iron and Steel Industry, by H. J. Kopineck and others, *Stahl und Eisen*, May 1959.

Effect of Arsenic, Copper, Tin, and Molybdenum on Impact Properties of Dead Soft Steel, by H. Sawamura and others, *Tetsu-to-Hagané*, January 1955.

NORMAN IRWIN STOTZ

An Appreciation
by C. T. Fletcher

Norman I. Stotz, AIME member since 1915, died Feb. 22nd at the age of 66. He was president of Braeburn Alloy Steel Corp., subsidiary of Continental Copper & Steel Industries Inc., and was a Director and Vice President of the latter.

Mr. Stotz attended the Colorado School of Mines and graduated from Lehigh University with a degree in metallurgical engineering. After a brief period as metallurgist with the Detroit Steel Products Co., he became night superintendent of its automobile spring div. In late 1917, he entered the United States Army and went immediately to France as metallurgist with the Motor Transport Corps.

Following World War I, he was employed at the Wyckoff Steel Co., Ambridge, Pa., as metallurgist, and in 1921 joined Braeburn Alloy Steel Corp. In 1925, he was made chief metallurgist and in 1928 became general superintendent, a position he held until 1935.

In 1935, he joined the staff of the Universal-Cyclops Steel Corp. It was during this period that he developed the 5 pct Cr-Mo air hardening die steel, which in the last decade has become one of the staple tool steel products. He was active in the development of new tool steels and in the advancement of melting, fabrication, and application of these steels. From 1942 to 1945, he served as acting manager of Universal's Titusville plant. Early in 1945, he returned to Braeburn Alloy Steel Corp. as President.

He was very active in technical societies, including the American Society for Metals, American Society for Testing Materials, American Society of Tool Engineers, and was a member of the American Iron & Steel Institute.

He was also very active in the AIME, serving on the Electric Furnace Steel Committee from 1946 to 1949. In 1949, he was Chairman of the Executive Committee of the Electric Furnace Steel Committee.

HARRY A. STRAIN

An Appreciation
by D. H. Regelin

Harry A. Strain, retired director of raw materials, fuel, and power of the Carnegie-Illinois Steel Co., died at his home on February 26th at the age of 74. Born February 18, 1886 at Clinton, Ill., he began his lifelong career in the steel industry as a clerk with the American Steel and Wire Co. A short time later, he joined the Illinois Steel Co. as a laborer in the Blast Furnace dept. of the Joliet plant. It was during this employment that he entered the Armour Institute of Technology. After leaving this school, he became stove tender at South works of the Illinois Steel Co. Two years later, he was transferred to the Milwaukee plant of the same company as superintendent of the Blast Furnace dept. Five years later, he returned to South works as superintendent of one of the blast furnace departments.

In 1921, he became superintendent of the Blast Furnace department of the Woodward Iron Co. at Woodward, Ala., returning to South works of the Illinois Steel Co. as assistant division superintendent, blast furnaces, and advancing to division superintendent three years later.

In 1936, he was promoted to assistant general superintendent at South works, and five years later was transferred to the Pittsburgh Office as director of raw materials, fuel, and power for the Carnegie-Illinois Steel Co. He retired from this position in May, 1951.

Upon his retirement, he served as a consultant for Fenimore Iron Mines, Ltd., becoming president and later, chairman of the Board of this company. After his resignation, he served as a consultant for a number of companies.

He was a member of the American Iron and Steel Institute, American Society for Metals, American Foundrymen's Association, the Blast Furnace and Coke Oven Associations of the Eastern and Western States, having served as President of the latter group in 1929-1930. He was particularly active in the AIME, having served for a number of years as a member of the Blast Furnace and Raw Materials Committee.

He will be long remembered for his Chairmanship of many thought-provoking sessions during the Annual Conferences of the Blast Furnace, Coke Oven and Raw Materials Committee.

NECROLOGY

Year Elected	Name	Date of Death
1957	Ballmer, Gerald J.	Mar. 9, 1960
1955	Bankson, J. P.	Unknown
1925	Brainin, Clement S.	Unknown
1947	Burrows, Lees J.	Unknown
1917	Cowan, William W.	Dec. 28, 1959
1905	Cowans, Frederick (Legion of Honor)	Sept. 7, 1959
1949	Deiss, Charles F.	Unknown
1958	Dresser, C. G.	September 1959
1947	Fox, Samuel R.	Unknown
1959	Garrison, Foster G.	Unknown
1923	Gilbert, John	Nov. 24, 1959
1919	Kett, Frederick F.	Mar. 12, 1960
1921	Kleinpell, Wm. D.	Apr. 21, 1959
1915	Larsh, Walter S.	Unknown
1914	Lathe, Frank E.	Jan. 15, 1960
1949	Lee, Whitford J.	Unknown
1928	Nicholls, Walter J.	Unknown
1903	Nutter, Edward H. (Legion of Honor)	Mar. 1, 1960
1957	Oosthuizen, E. D.	Dec. 25, 1959
1939	Rheinheimer, O. C.	Mar. 8, 1960
1946	Shaw, Don W.	Unknown
1945	Shefelbine, G. H.	Feb. 24, 1960
1928	Spencer, Kenneth A.	Feb. 19, 1960
1915	Stotz, Norman I.	Feb. 22, 1960
1944	Swett, Hubert C.	Feb. 11, 1960
1943	Uhrig, L. Vernon	Unknown
1917	Wilson, Malcolm E.	Jan. 30, 1960
1953	Wingfield, George	Dec. 25, 1959

OBITUARIES

Hubert C. Swett, chief metallurgist for the Bethlehem Steel Co.'s Pacific Coast div., died in Bethlehem, Pa., Feb. 11th, at the age of 55. He joined Bethlehem Steel in 1924 as a chemist, and was an AIME member since 1944. A surviving son, Eugene, is supt. of mills at the Co.'s San Francisco plant.

John P. Bankson and **Foster G. Garrison**, former members of the Pittsburgh section, are among the deaths recently reported. At his death, Mr. Bankson was involved in special sales for the Koppers Co. Inc. He began his career with General Refractories Co. in 1922, and first joined the AIME in 1946 as an associate member.

Mr. Garrison, a member since May 1959, was director of market research for the Columbia-Southern Chemical Corp. at his death. He had been with the Corp. since 1937, when it was known as Southern Alkali Corp.

Coming Events

May 9-11, Society for Nondestructive Testing, Second Southwest Regional Convention, The Baker Hotel, Dallas.

May 9-13, American Foundrymen's Society, National Castings Congress and Exposition, Convention Hall, Philadelphia.

May 9-13, American Society for Metals, Southwestern Metal Exposition and Congress, State Fair Park, Dallas.

May 23-26, AIME Symposium on Refractory Metals and Alloys, McGregor Memorial Conference Center, Wayne State University, Detroit.

May 26, Buffalo Section, Golf Party, Wanakah Country Club, Buffalo.

May 26-27, The Metallurgical Society, New England Regional Conference on *New Developments in Metalworking*, Statler-Hilton Hotel, Boston.

June 3, Southern Ohio Section, NOHC, Golf Outing, Elks Country Club, Portsmouth, Ohio.

June 8, Northern Ohio Section NOHC, Golf Party, Squaw Creek Country Club, Youngstown, Ohio.

June 9-10, AIME Columbium Symposium, sponsored by the Hudson-Mohawk section, Hotel Sagamore, Lake George, N. Y.

June 13, Pittsburgh Section, NOHC, Golf Party, Mt. Lebanon Country Club, Pittsburgh.

June 13-15, First International Powder Metallurgy Conference, Hotel Biltmore, New York, under joint auspices of AIME and MPIF.

June 18, Cleveland Section, NOHC, Dinner-Dance, Lake Shore Hotel, Cleveland.

June 20, Eastern Section, NOHC, Golf Party and plant trip, Plymouth Country Club, Plymouth Meeting, Pa.

June 20-24, American Society for Engineering Education, 68th annual convention, Purdue University, Lafayette, Ind.

June 26-July 1, American Society for Testing Materials, Annual Meeting and apparatus exhibit, Chalfonte-Haddon Hall, Atlantic City, N. J.

July 11-12, AIME Conference on the Response of Materials to High-Velocity Deformation, Estes Park, Colo.

Sept. 1, Chicago Section, NOHC, Golf Outing, Gleneagles Country Club, Chicago.

Sept. 15-16, Eighth Annual Engineering Management Conference, Morrison Hotel, Chicago.

Oct. 3, Chicago Section, NOHC, Fall Dinner Meeting, Phil Smidt's Restaurant, Hammond, Ind.

Oct. 5-7, Rocky Mt. Minerals Conference, Newhouse Hotel, Salt Lake City.

Oct. 13-14, Southwestern Section, NOHC, Fall Meeting, Statler-Hilton Hotel, Dallas.

Oct. 17-21, Fall Meeting of The Metallurgical Society of AIME, Sheraton Hotel, Philadelphia.

Jan. 18, 1961, Conference on Bar and Allied Products, sponsored by Mechanical Working Committee of The Metallurgical Society, Penn-Sheraton Hotel, Pittsburgh.

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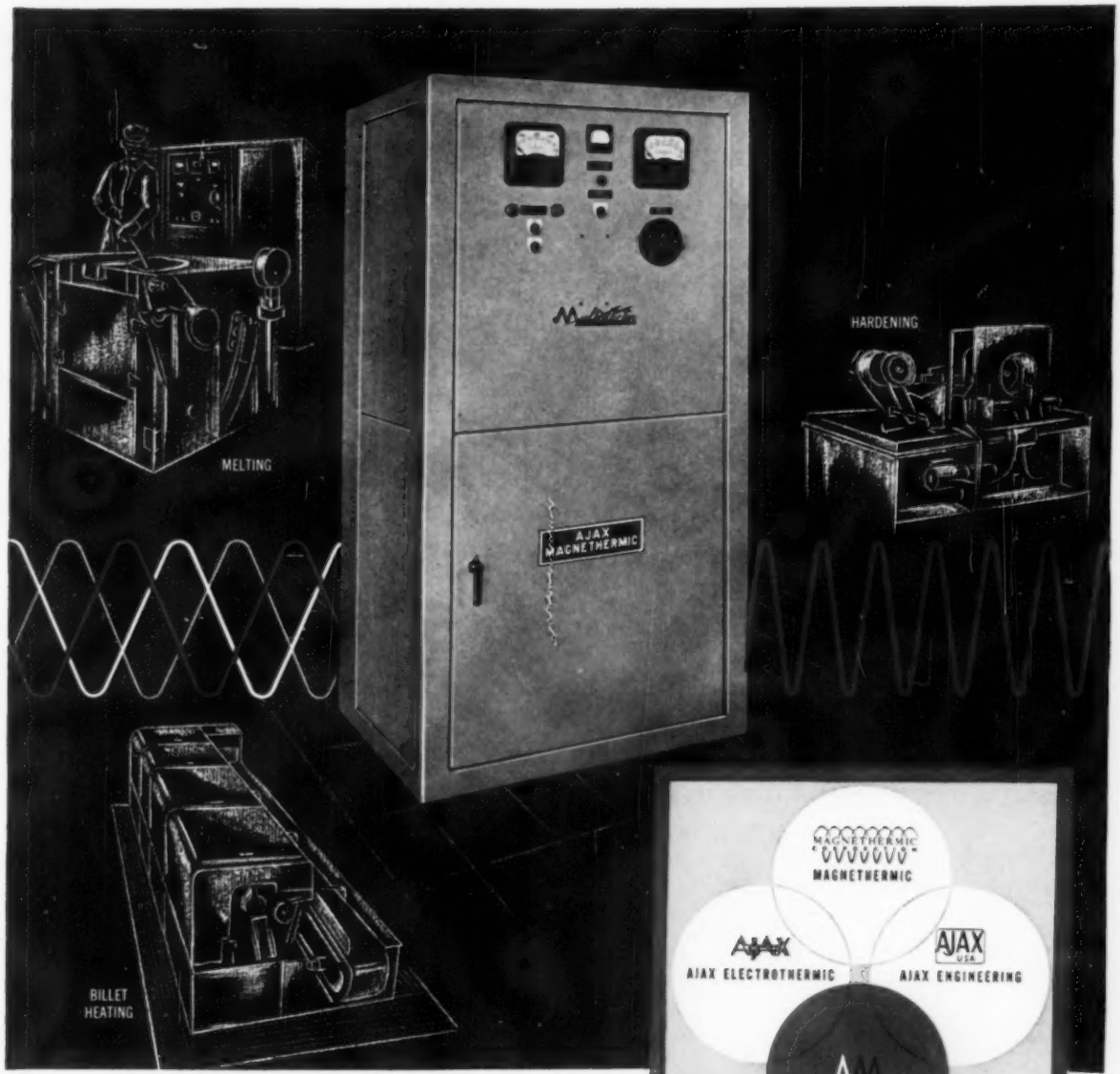

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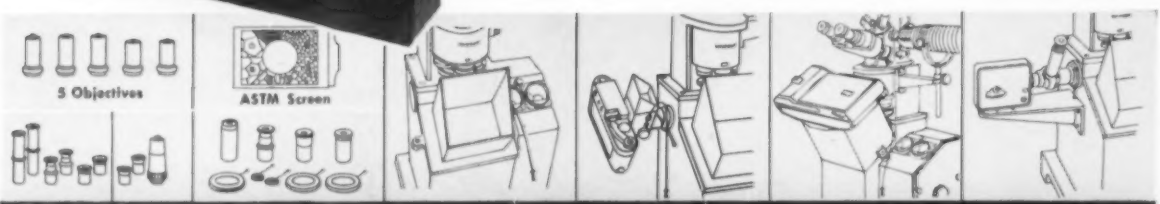

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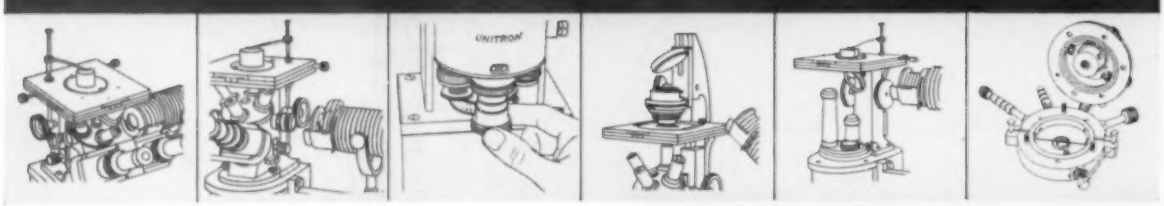

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